NOVEMBER, 1959

Welding Journal

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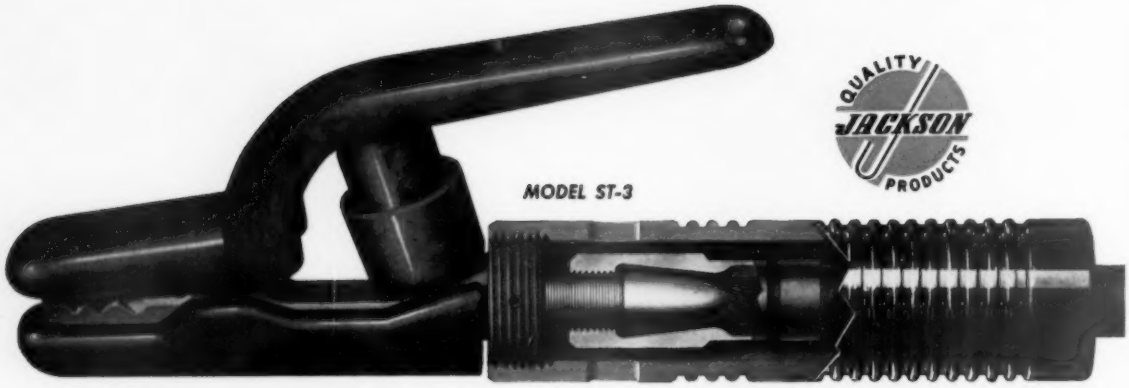
FFICIAL PUBLICATION OF THE AMERICAN WELDING SOCIETY



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JACKSON SERIES ST electrode holders offer a *Sealed Tight* mechanical cable connection that gives you practically one-piece conductivity between cable and holder. Tongs are of heat-treated 98% copper alloy.

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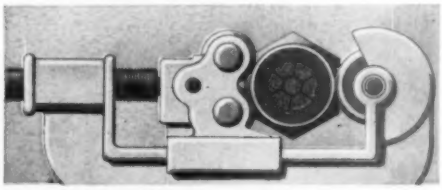
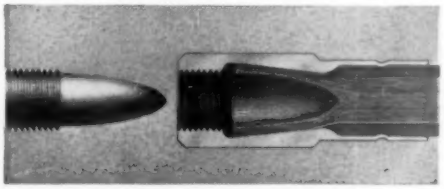
The nut extends backward, forming a ferrule around the cable jacket. This *Sealed Tight Connection Nut* is made in sizes to fit cables No. 1, 1/0, 2/0, and 3/0.



For a *truly permanent nut-to-cable connection*, the ferrule of the nut is crimped around the cable jacket, using Jackson's inexpensive, fast-acting crimping tool.



Detachable Stinger feature enables the operator to detach the "stinger end" by unscrewing it from the connection nut. The cable strands stay in place inside the nut.

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PRESS-TIME NEWS ...about ...People ...Welding ...Products

Hon. Herbert Hoover Breaks Ground for United Engineering Center

Citing the engineering profession as "the foundation of security in our defense and the increase of our standards of living and comfort," former President Herbert Hoover, on October 1st, led the ground-breaking ceremony for the United Engineering Center facing the United Nations Plaza in New York City. The building will house headquarters of the AMERICAN WELDING SOCIETY and 17 other engineering groups when it is completed in 1961, at an estimated cost of $12,000,000.

Mr. Hoover hailed the event "of national importance" and went on to say, "The engineering societies are in reality a great educational institution. Within the societies is the constant exchange of discovery, improvements and experience. Their findings are printed for all the world to see." He continued, "These societies also constitute a gigantic postgraduate course" which "continues all their professional lives."

Symbolically representing the engineers of the future was Jerry Fujimoto, aged 18, of Hawaii who was described as coming from the newest state in the Union and entered in the newest engineering class of Rensselaer Polytechnic Institute, the oldest engineering college in the USA. The former president, representing the older generation of engineers, was joined by Mr. Fujimoto as together they broke the ground.

The audience, among whom were representatives from a dozen nations, listened to speeches from the officers of the United Engineering Trustees who described the history, the progress to date and the future plans for the 18-story building which will occupy the block front on 1st Avenue between 47th and 48th Sts. Welcoming and introductory remarks were made by Andrew Fletcher, president of UET, who pointed out the growth and importance of science and technology and the invaluable service rendered by engineering societies.

This was followed by an address from Willis F. Thompson, vice-president and chairman of UET's real-estate committee, who described the work done in bringing the plans to their present state and indicated some of the advanced features to be incorporated in the building.

Richard E. Dougherty, chairman of the Trustees' member gifts committee expressed his confidence that members will renew and intensify their efforts to reach the as-yet unpledged quota of $1,100,000.

Mervin J. Kelly, who heads the industrial compaign section, publicly thanked the more than 500 corporations and 56,000 engineers and friends whose contributions to date have warranted the start of construction. He cautioned against undue optimism: ". . . we must not overstate our position. As generous as has been the response, as yet we do not have pledged all funds required for a center free and clear of debt encumbrance. This is our goal and towards it we shall work with even greater zest and determination."

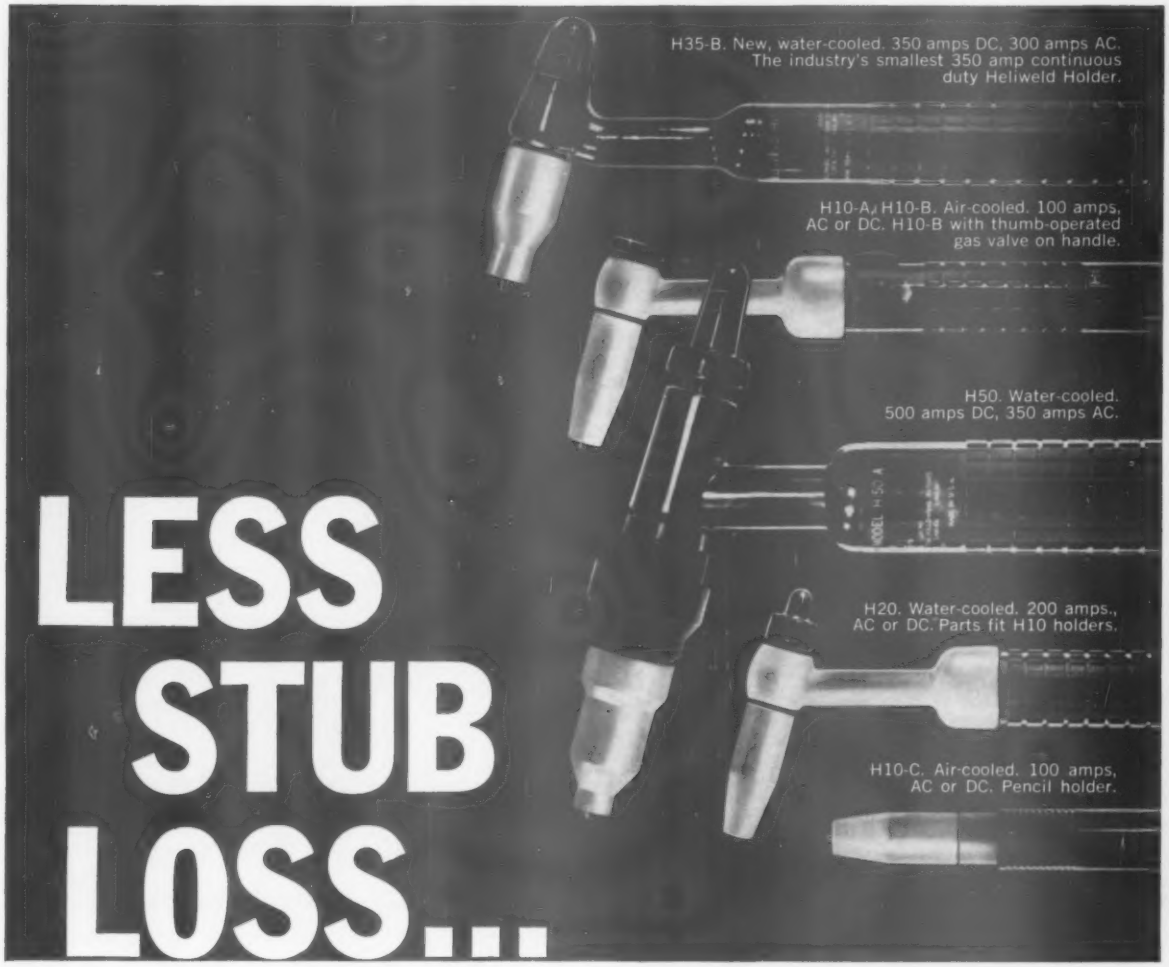
Each of the speakers in various ways emphasized the importance of the project which was summed by the simple closing words of Mr. Hoover's address: "It will play a great part in American life. It will serve all mankind."

Ownership and operation of the new building will come under the United Engineering Trustees, a group formed by the societies for that purpose, who now own and operate the 52-year old building on 39th St.

The Honorable Herbert Hoover emphasizes the important role played by the engineering societies in the development of the engineering profession

Jerry Fujimoto of Hawaii shares honors with the former President, symbolizing the joining of the future with the older generation of engineers

The architect's conception of the United Engineering Center illustrates the slim, functional lines of the future headquarters for the societies' 300,000 members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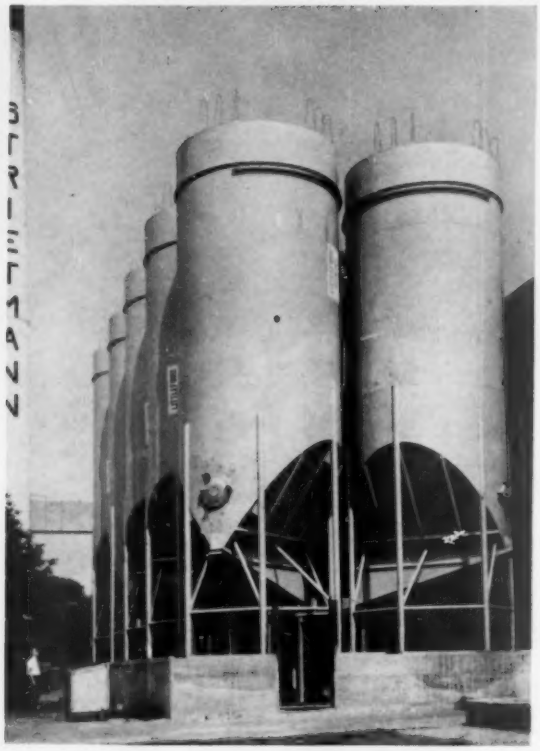
WELDING ZONES

This 27-ft-diam waterwheel generator half "spider" is being welded at Westinghouse Electric Corp.'s East Pittsburgh, Pa., works. The 25-ton piece will be joined with its matching half for installation in one of the thirteen 167,000-kva waterwheel generators for the $720-million New York State Power Authority's Niagara Power Project.



Ten all-welded bulk-flour-storage bins, each 12 ft in diam and 41 ft high, have been designed to permit clean and efficient storage of flour. Fabricated by Littleford Bros., Inc. of Cincinnati, Ohio, these bins are the largest of their kind ever to be shipped by truck through Cincinnati. A steel and brick building will enclose the installation on the foundations shown.

One of six aluminum pneumatic unloading trailers now being used for hauling highly sensitive polystyrene plastic is shown at the new Cosden plant at Big Spring, Tex. The 28-ft long aluminum units were designed and built by Sprout, Waldron & Co., Inc., of Muncy, Pa., as completely welded units. (Courtesy Kaiser Aluminum & Chemical Corp.)

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WORLD-WIDE WELDING NEWS

By Gerard E. Claussen

CZECHOSLOVAKIA

Welding Rectifiers

The February issue of Halies contains an article on a stepless voltage regulator for 700-amp constant-potential welding rectifiers.

FRANCE

New Charpy Requirements Established in Shipbuilding

Bureau Veritas, in its 1958 edition of the rules for building steel ships, has introduced new Charpy requirements for ES and ES Special steels in the 58,500 to 74,000 psi tensile range. ES steels must now absorb 15 ft-lb impact at −40° F in keyhole value and 30 ft-lb at 32° F for Charpy-V value. ES special steels are now required to withstand 15 ft-lb at −76° F for keyhole and 30 ft-lb at −4° F for Charpy-V values.

SOVIET UNION

Effect of Heat Treatment on Notch-impact Strength

The effect of local heat treatment on the notch-impact strength of welds in high-tensile steel is discussed by O. L. Bandrishev in the November 1958 issue of *Metallovedeny 1 Obrabotka Metallov.*

Automatic Welding Magazine

The November 1958 issue of *Avtomaticheskaya Svarka* contains eleven articles of interest.

The arc casting of ingots of high-speed steel and other steels 8 in. in diameter is performed by the electro-slag process using fluxes containing fluorspar. The ingots were particularly free from defects.

The distribution of hydrogen in submerged-arc deposits of austenitic and ferritic steels on a steel containing 0.32% C and 0.90% Cr was determined qualitatively by spreading a thin film of dehydrated glycerin over the polished surface and observing bubbles. Hot vacuum extraction on slices cut from several levels in the deposits showed six times as much hydrogen in the heat-affected zone of the austenitic deposit as in the same zone of the ferritic deposit. This was difficult to reconcile with the hydrogen theory of heat-affected-zone cracks.

Two other articles describe a controlled-atmosphere chamber for welding reactive metals and the rapid spectroscopic determination of carbon in steel welds.

High-speed motion pictures of aluminum electrodes in argon and helium showed that the transition current at which electromagnetic pinch effect became effective in creating small drops was about the same in both gases. The transition current rose from 120 to 200 amp as the electrode diameter was increased from 0.059 to 0.10 in. Jet transfer was not observed with aluminum, although it occurred with stainless-steel electrodes of 0.079 in. diam at 480 amp.

The rate of corrosion of Type 321 stainless-steel welds in boiling 6% sulfuric acid was reduced to almost nil by aerating the acid or by the addition of 0.5% nitric acid.

Charts show the speed at which air carbon-arc equipment cuts stainless steel up to 1 in. thick.

The desulfurizing capacity of seven fluxes for the electro-slag casting of steel was determined. The best flux consisted of CaF_2 + CaO + Al_2O_3 + MgO, although the percentages were not given.

The effect of unsymmetrical voltage on transformers for three-phase arc welding is worked out mathematically.

The electro-slag principle is applied to the hot topping of steel ingots to increase yield and reduce segregation.

The final article is a discussion of the microstructure of brittle fractures in mild-steel impact bars broken below the transition temperature. Isolated cracks free from plastic action preceded the main crack, which was accompanied by some plastic deformation.

Phosphorus Segregation

An article in the February 1959 issue of *Avtomaticheskaya Svarka* described a study of the segregation of phosphorus in electroslag welds in plain-carbon steels using radioactive tracers. Segregation was insignificant with 0.20% C, but was pronounced with 0.39% C. Phosphorus segregated in the ferrite and lowered the notch-impact value, which was later raised by normalizing.

Other articles discussed the reciprocal effects of transient processes in the arc with consumable electrodes and transient processes in the power supply; the microstructure of weld metal containing 0.30% C, 9% W, 2% Cr, 0.4% V at cooling rates of 0.01 to 63° C per second at 700° C and identified the Fe-Si-Al phases in aluminum weld metal.

Varied Welding Aspects Are Covered

Hard surfacing of steel with white cast iron by the submerged-arc process; a microstructural study of the junction zone in welding austenitic stainless steels to plain-carbon steels, and a contour cutting machine for the submerged-arc welding of complex contours are among the articles in the February 1959 issue of *Avtomaticheskaya Svarka.*

Other articles describe the condenser-discharge and resistance butt welding of steel wire rope; the application of electro-slag welding to the welding of short joints; and the electro-slag welding to cast iron at 600 to 900 amp with a cast-iron strip electrode.

Dr. GERARD E. CLAUSSEN is associated with Arcrods Corporation, Sparrows Point, Md.

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Weight —
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with long cap: 3.6 oz.

Length overall — 6⅞ in.

Length of Torch Head —
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with medium cap: 3-9/32 in.
with long cap: 7-5/16 in.

Maximum Handle Diameter — ¾ in.

Maximum Head Diameter — 9/16 in.

Service Lines — 12½ or 25 ft.

*Torch is supplied with medium cap for 3-in. electrodes. Short cap for 2-in. electrodes and long cap for 7-in. electrodes are available as accessories.

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Various Processes Employed in Pipe-line Welding

The welding of gas and oil pipe lines is the subject of seven feature articles in the February 1959 issue of *Svarochnoe Proizvodstvo*. Equipment for resistance-butt welding in the field of pipe joints up to 20 in. diam is described in one article. In a work-day shift 132 joints can be welded by a 17-man crew, compared to 35 joints with manual-arc and 46 joints with submerged-arc welding. Equipment is now being developed to weld 40-in. pipe.

A second paper describes the heating by proximity effect of the longitudinal seams of pipe prior to pressure welding.

A third paper advocated CO_2 welding with mechanized travel for butt welds in field fabrication of pipe. A 0.039-in. diam silicon-manganese steel electrode is fed through two heads, each one performing 180 deg of the joint, beginning at the top in two passes. Current and speed are lower in the overhead than in the top portion of the joint; the current ranged from 110 to 160 amp and from 19 to 21 v. During the first pass, the electrode is oscillated from 0.08 to 0.20 in., increasing to 0.55–0.71 in. during the second pass. Welds have been made on 6- to 28-in. diam pipes, with wall thicknesses up to $^3/_8$ in. diam, using such procedures.

The double lengthening of pipes —as many as six at one time—is performed by automatic submerged-arc welding before being transported to site. Twenty-inch diameter pipe with $^3/_8$-in. wall thickness is welded at 280–350 amp. Welding is completed with $^5/_{64}$-in. wire in three passes, reaching speeds of 15 ipm.

A mobile laboratory is also described which performs inspection of welds in pipe lines. Equipment consists of Cesium 137 isotope and a magnetic de.ectoscope.

High impact values in submerged-arc welds were attained from a silica-free flux, containing fluorides and an addition of alumina. A 0.10-in. diam electrode, composed of 0.10% C, 1.08% Si, 1.23% Mn, 1.75% Ni, 0.006% S and 0.017% P, was used to weld a similarly alloyed steel, 0.20% higher in carbon content, at 170 to 230 amp. The weld metal, after being heated to 1650° F and isothermally transformed at 608° F, had a 160,000 psi tensile strength and an impact value at −108°F of 28 ft-lb.

In another article a nomogram is explained for computing carriage and shaft speeds in submerged-arc surfacing of 2- to $3^1/_2$-in. diam steel shafts.

WEST GERMANY

This welded dock crane was built by Krupp-Ardelt GmbH, Wilhelmshaven, West Germany. It has a working capacity of 5 tons with a 10 ton maximum and a boom of 55 ft. (Courtesy of "Schweissen und Schneiden")

WEST GERMANY

Low-hydrogen Electrodes

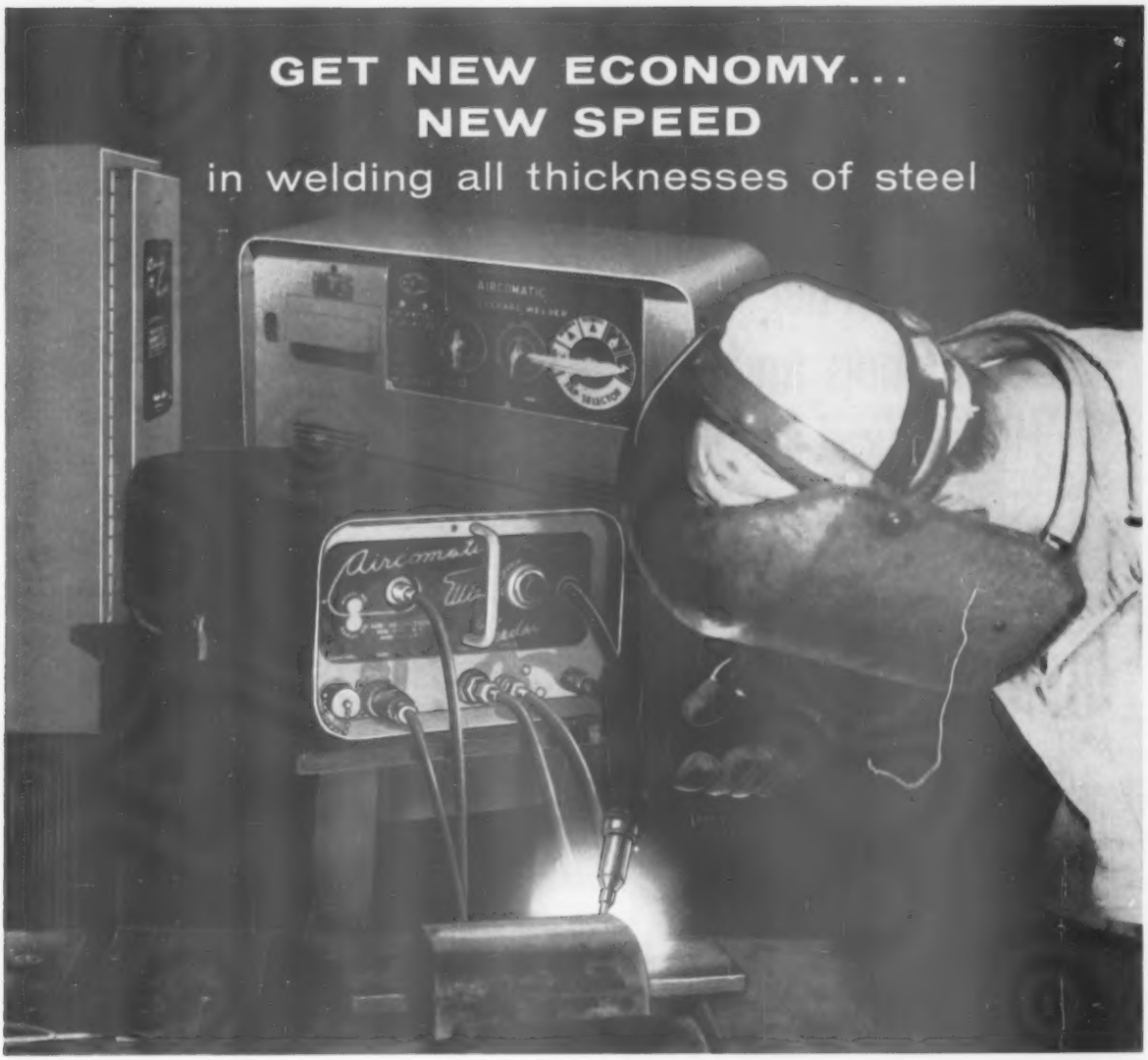
The West German welding magazine *Schweissen und Schneiden* for April 1959 contained articles on absorption of atmospheric moisture by low-hydrogen electrodes, on defects in gas welds, and on membrane vibrations in welded structures.

Low-hydrogen electrodes have been developed which absorb moisture from humid atmospheres at about 15% of the rate exhibited by previous formulations. Some of the factors favoring low absorption rate were: moisture repellants, minimum quantities of waterglass binder, high extrusion pressure and avoidance of fine raw materials.

German Welding Progress

This issue also contained a company-by-company description of the welding exhibits at the Hanover Industrial Fair. Abstracts were given of the following papers presented at the flame cutting conference in Essen, Jan. 28, 1959:

1. New Flame-cutting Machines; Construction and Application
2. The Present Position of Flame Scarfing
3. Accuracy Attained with New Automatic Cutting Torches
4. Acetylene and Propane for Stock Cutting
5. Propane for Flame Cutting
6. Fatigue Strength of Flame Cut and Weld-repaired Steel
7. Thermodynamics of Flame Cutting
8. Cutting Nonferrous Metals
9. The Effect of Tip Design on Cutting Speed and Quality with Propane



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Titeflex operator brazes assembly with torch and hand-fed Handy & Harman Alloy BRAZE 541. *Titeflex is unique in that it makes flexible hose assemblies from raw material to end product—"From End to End, Inside and Out, made RIGHT In Our Own Plant."*

This Springfield, Massachusetts, manufacturer of aircraft and missile fuel, lubrication and hydraulic lines finds that silver alloy brazing with Handy & Harman BRAZE 541 meets rigid operating requirements "all the way down the line."

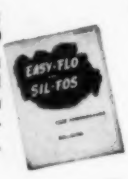
The tubing and fittings of many of the wide range of assemblies made by Titeflex are 321, 316 and 347 stainless steel and Monel. Brazing is a hand torch, wire and HANDY FLUX operation.

BRAZE 541 is a plastic alloy which melts at 1325° F and flows at 1575° F. Its strength—in shear—at elevated temperatures is 21,500 psi at 500° F and 15,000 psi at 750° F. This alloy's ductility in resisting stress and vibration is very high and its resistance to oxidation and corrosion is equally impressive. The composition of BRAZE 541 is 54% silver, 40% copper, 5% zinc and 1% nickel. It meets AMS Specification 4772.

Aircraft and missile component manufacturers and fabricators are finding—to their and their products' benefit—that Handy & Harman silver alloy brazing is the full and *final* solution to their metal-joining problems. BRAZE 541 is but one of a large family of Handy & Harman alloys, for both low and high temperature applications. We would like to more fully acquaint you with BRAZE 541 and with the advantages that come naturally to silver brazing as a metal-joining (both ferrous and nonferrous) method. Handy & Harman, 82 Fulton Street, New York 38, N. Y.

FOR A GOOD START: BULLETIN 20

This informative booklet gives a good picture of silver brazing and its benefits . . . includes details on alloys, heating methods, joint design and production techniques. Write for your copy.



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The Role of AWS

The rash of failures of welded ships during World War II sharply focused the attention of steel fabricators and steel producers upon the problems of brittle fracture. The investigations and research initiated because of this wartime crisis alleviated the immediate problem. The research program continues, for the areas of our ignorance of brittle fracture and the failure of steel structures are still large. Yet we have learned much which enables us to reduce greatly the chances of catastrophic failure.

Meanwhile, our rapidly expanding technology places increasing demands upon welding science. In the field of shipbuilding, the rapid increase of vessel size confronts us with the problem of joining plates of far greater thickness than those previously used. Developments in the power and chemical industries create problems of welding high-alloy steels as well as the problem of increased thicknesses. Nuclear-power developments pose similar and often greater challenges to the welding industry.

In meeting these new demands and challenges, the AMERICAN WELDING SOCIETY plays a unique and critical role. It is obvious that if the demands of advancing technology are to be met, welding research must be maintained at present or even higher levels and, of equal importance, the knowledge and insight that result from this research must be interpreted and disseminated to those engineers and technicians responsible for its use. One thing we have learned is the need for intelligent understanding and high craftsmanship at all stages of the welding process—in material selection and production, in detail joint design, in fabrication and in the inspection of completed structures. By providing the forum which allows the broad variety of scientists and engineers associated with welding to meet and discuss their problems, the AMERICAN WELDING SOCIETY stands as the focal point where research and practice combine to contribute an essential part in advancing the state of the art.

Rear Admiral E. H. Thiele

ENGINEER-IN-CHIEF
U. S. COAST GUARD

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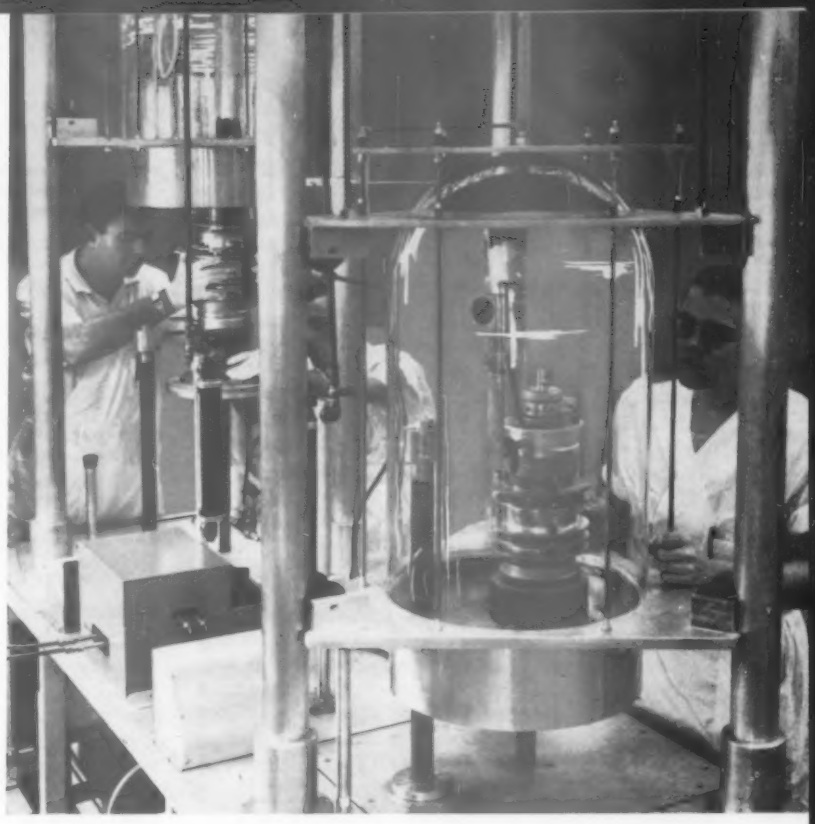

Fig. 1—Bell-jar arrangement for fluxless brazing Klystron tube assemblies in controlled atmosphere. Dual-station fixture served by single 10-kw generator permits brazing at one station while operator prepares assembly in other station. Several joints are made in sequence (see Fig. 3)

High-Frequency Induction Brazing and Soldering

find application in many industries concerned with metal fabrication

BY JOSEPH LIBSCH AND PAT CAPOLONGO

Introduction

In recent years, many complex forgings and stampings have been redesigned to allow fabrication by brazing or soldering of parts produced by mass-production techniques. Such new designs have often resulted in striking reductions in cost. In other instances, brazing and soldering have permitted the construction of assemblies too costly or complex to be produced by other techniques.

Induction heating has proved to be a valuable aid in these joining processes for many reasons. Among these are rapid heating and precise heat control. The former offers the possibility of localized heating for joining high-strength components with minimum loss of strength. The latter permits sequential brazing or soldering operations to be performed effectively. Rapid heating also minimizes discoloration and thus facilitates cleaning. Uniform joints with smooth fillets, obtained by induction soldering and brazing, decrease alloy consumption and produce parts which are identical in appearance.

A primary advantage of induction heating in brazing and soldering applications is its ready adaptation to production-line methods, permitting strategic arrangement of the equipment in an assembly line and, if necessary, heating by remote electrical command and control. Frequently, induction brazing and soldering permit a reduction in the required number of holding fixtures. At the same time, the resultant minimum heating of the fixtures increases their life and maintains their accuracy in alignment of the components to be joined. If necessary, induction brazing or soldering may be conducted in isolating environments; such as in controlled atmosphere or vacuum.

Since operators need not guide the induction-heating source, both hands are left free to prepare assemblies for joining. The operation is simplified so that semiskilled help can release highly skilled personnel for other tasks. Finally, induction heating improves the working environment.

It is not surprising, therefore, that induction heating has been widely accepted for brazing and soldering operations. The advantages of the induc-

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tion method are fully realized, however, only when the proper procedures and joint design are adapted to this method of heating. These procedures are described in this article.

Joining Alloys and Fluxes

Basically, brazing and soldering involve fusion of a joining alloy between the surfaces of metal parts to be joined. If the metal surfaces are clean, intimate contact is established and the joining material alloys with each surface, forming a joint upon solidification during cooling. The two methods of joining differ primarily in the type and melting temperature of the alloy used to form the joint.

Soldering Alloys

In soldering, low-melting-temperature alloys, generally containing lead and tin, permit joints of limited strength to be made at temperatures below 800° F. Soldering with these alloys is often termed *soft soldering* and is used in fabricating radio condenser cans, radiators, terminal strips, instrument cases, etc.; with the metals to be joined consisting of copper and copper alloys such as brass and bronze, carbon and alloy steels, nickel and nickel alloys and clad or plated aluminum.

Table 1 lists the joining alloys commonly used for induction soldering with their chemical compositions and melting ranges. The eutectic alloy, No. 2, and alloys Nos. 3, 4 and 5 are used most extensively for induction soldering. The lead-silver alloys flow at higher temperatures than the lead-tin alloys and are sometimes useful in sequential soldering, i.e., when nearby solder joints must be made in sequence without affecting the previous joint. While small amounts of antimony, silver, bismuth and other elements are sometimes reported in lead-tin solder alloys, their exact influence is controversial and their benefits in induction soldering dubious. Excellent results have been obtained with the standard lead-tin alloys.

Aluminum alloy parts to be joined may be tin plated and then joined with the common lead-tin alloys; or they may be joined with proprietary alloys, generally of tin-zinc or tin-cadmium composition. Soldering alloys for joining aluminum and its alloys must be selected with care. Since all solders have solution potentials significantly different from those of aluminum alloys, soldered joints may disintegrate rapidly as a result of galvanic corrosion when exposed to moisture.

Most solder alloys are commercially available in the form of wire, strip and powder. Different sizes of wire and strip permit conservation of alloy. In addition, preforms in the shape of washers, rings, etc., are commercially available or may be prepared for preplacement at the joint area prior to heating. Such preforms have found wide application in induction soldering. On the other hand, powdered joining alloys have found very limited application because of difficulty in controlling the amount of alloy and also the displacement of the alloy from the joint as the flux spatters during heating.

Table 1—Chemical Composition and Melting Range of Alloys Commonly Used in Induction Soldering[a]

Alloy	Tin	Lead	Silver	Melting Range, ° F	
				Liquidus	Solidus
1	99.8	...	..	450	450
2	62	38	..	361	361
3	60	40	..	370	361
4	50	50	..	420	361
5	40	60	..	460	361
6	30	70	..	500	361
7	...	97.5	2.5	590	590
8	...	96.5	3.5	603	590

[a] Additional alloys are available. For special problems relating to alloy selection, it is recommended that prospective users consult their suppliers of alloys.

Soldering Fluxes

Thorough cleaning prior to and during heating is basic for successful solder joints. Many joint failures may be traced directly to poor cleaning and inadequate fluxing. Surfaces to be joined should be chemically cleaned (freed of heat treatment scale, corrosion products, grease, embedded graphite, etc.) prior to heating, and the joint areas fluxed as soon as possible to avoid contamination from handling or exposure.

Suitable fluxes prevent oxidation of the joining alloy and metal surfaces to be joined and also help to dissolve any residual oxides during heating. They improve the wetting characteristics of the joining alloy, thus promoting its free flow upon melting. Zinc chloride, aluminum chloride and ammonium chloride fluxes in paste form are most frequently used in induction soldering, since they are the most active. Unfortunately, these fluxes leave residues which are corrosive, electrically conductive and hygroscopic. Such flux residues must therefore be thoroughly removed. When this is impossible, as in soldering fine electrical assembly units, rosin or activated rosin-type fluxes which leave noncorrosive and electrically nonconductive residues are used. Flux-cored solder containing the flux within the solder-wire has not proved desirable for induction soldering, since the flux is entrapped until the solder melts and therefore is not initially present to protect or clean the surfaces to be joined. Recently developed solder-wire with external flux coatings avoids this difficulty.

Recent experiments using hydrazine derivative fluxes offer good promise for induction soldering of copper, brass and other copper alloys where corrosion from residual flux deposit is a problem. During the soldering operation, while the temperature is in the range of 375° to 600° F, the hydrazine flux rapidly decomposes and vaporizes, leaving a small amount of essentially inert flux residue. Special proprietary fluxes to facilitate soldering of stainless steels, printed-circuit soldering and soldering of brasses subject to season cracking, are also available from manufacturers of soldering alloys and fluxes.

Fluxes for induction soldering are usually used in

paste or liquid form, the flux being applied to the surfaces forming the joint and the preplaced solder preform prior to heating, by dipping, spraying or brushing. To avoid spattering, the flux should not be highly diluted.

Fluxless Soldering

A recent development is the use of ultrasonic energy in fluxless soldering and as an aid in joining aluminum alloys. Ultrasonic vibrations aid in removing oxide films and cleaning the surface, permitting the joining material to alloy with the clean metal surfaces. Experimental work indicates that the use of ultrasonic energy may be particularly effective in induction soldering aluminum alloy parts without the need for plating prior to joining. Figure 2 shows an arrangement utilizing ultrasonic energy to assist in joining steel cases to electrical terminal bases in the absence of flux.

Brazing Alloys

Brazing alloys melt at considerably higher temperatures, and provide high-strength joints which can resist reasonably elevated temperatures without failure. Cutting torches, carbide-tipped tools, structural frames, musical instruments, jewelry, ice skates, etc., are frequently fabricated by brazing. The metals to be joined include carbon and alloy steels, stainless steel, cast iron, copper and copper alloys, nickel and nickel alloys and, to limited extent, aluminum alloys.

Table 2 lists the joining alloys commonly used for induction brazing with their compositions, approximate melting temperatures and also their color for matching the parts to be joined. As indicated in Table 2, a variety of alloy materials are used for induction brazing. The selection depends upon the melting-temperature range; ability to wet the metallic surfaces to be joined; the tendency of alloy components to oxidize and/or volatilize; the strength and ductility of the alloy and, in some instances, unfavorable metallurgical reaction with the metals to be joined. With the exception of controlled-atmosphere brazing, copper and brass are not preferred as joining alloys in induction brazing because the high temperature required for making the joint slows production and causes a breakdown of the common fluxes with the result that cleaning becomes difficult.

Silver brazing alloys are most extensively used in induction heating since they may be used to join both ferrous and many nonferrous metals and provide joints with good strength and corrosion resistance. The various compositions indicated permit joining temperatures from approximately 1150° F (Alloy 4) to 1780° F (Alloy 12). Alloy 5, exhibiting a wide melting range, i.e., 1125–1295° F, is more sluggish with respect to flow and is particularly useful for building up or filleting poorly fitted joints. The addition of nickel in Alloy 6 and the use of manganese in Alloy 12 promote wetting and improve bonding when joining cemented carbides, stainless steel, stellites and other refractory alloys. The ternary alloy of silver, copper and phosphorus (Alloy 2) is frequently used for joining copper and copper alloys. It is largely self-fluxing when used with copper, but should not be used on ferrous metals since it forms a brittle iron phosphide. The eutectic alloy (No. 1) has been found particularly useful in controlled-atmosphere brazing by induction without flux because it is free of the volatile components, zinc and cadmium. The eutectic alloy containing lithium (Alloy 11) shows some promise in assuring high-quality joints when brazing without flux in a controlled atmosphere. Alloys with large amounts of silver (Alloy 8) permit a good color match when joining silver parts. The nickel-chromium alloy (Alloy 14) is used chiefly for joining stainless steels and high-nickel alloys that are subjected to high temperatures. Since high joining temperatures are used, interfering oxides are reduced if brazing is done in a dry-hydrogen atmosphere, thus eliminating the need for flux (see Atmosphere

Table 2—Chemical Composition, Melting Range and Color of Alloys Commonly Used in Induction Brazing[a]

Alloy No.	AWS spec.	Silver	Copper	Zinc	Cadmium	Other	Solidus, °F	Liquidus, °F	Color
		%							
1	BAg-8	72	28	...	..	...	1435	1435	White
2	BCuP-5	15	80	...	..	5 P	1185	1445	Gray
3	BAg-1a	50	15.5	16.5	18	...	1160	1175	Yellow
4	BAg-1	45	15	16	24	...	1125	1145	Yellow
5	BAg-2	35	26	21	18	...	1125	1295	Yellow
6	BAg-3	50	15.5	15.5	16	3 Ni	1170	1270	Yellow
7		54	40	5	..	1 Ni	1340	1575	Off-white
8	BAg-9	65	20	15	..	...	1235	1325	White
9		10	52	38	..	...	1410	1565	Yellow
10	BCu	...	99.9 min	...	..	...	1981	1981	Copper
11	BAg-8 + 0.2 Li	71.8	28	...	..	0.2 Li	...	...	White
12	BAg-Mn	85	...	...	..	15 Mn	1760	1780	...
13	BCuAu-1	...	Rem.	...	..	Au 37.5	1770	1825	...
14	BNiCr	(Ni 65/75, Cr 13/20, B 3/5, Fe + Si + C, 10 max)					1850	1950	...
15	BAlSi-4	(1 1/13 Si, remainder Al)					1070	1080	...

[a]Additional alloys are available. For special problems relating to alloy selection, it is recommended that prospective users consult their suppliers of alloys.

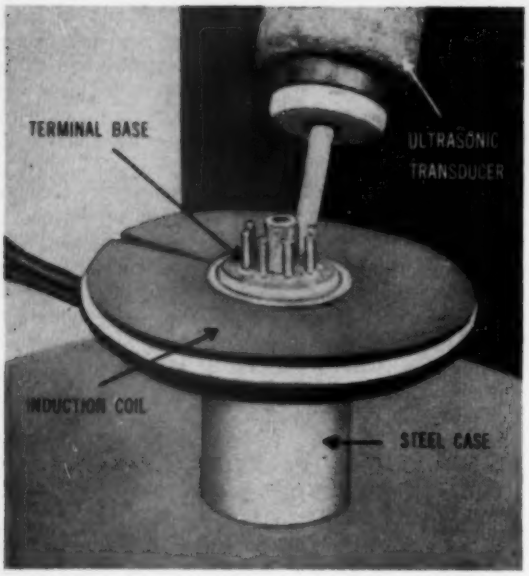


Fig. 2—Ultrasonic energy aids in joining steel cases to electrical terminal bases without flux. The pie-plate induction coil selectively heats the base of the steel case and melts a preformed solder ring. The transducer supplies ultrasonic energy to the molten alloy insuring a good bond.

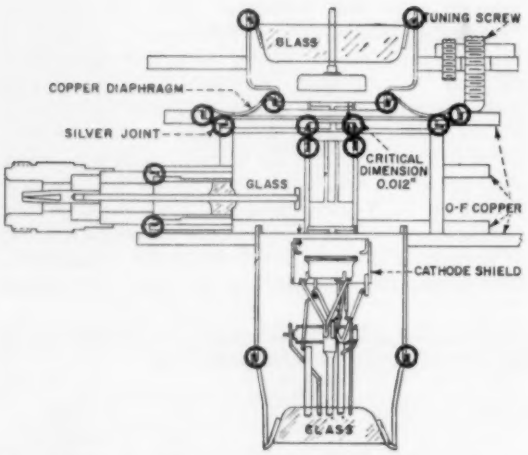


Fig. 3—Schematic diagram illustrating induction-brazed joints in the assembly of Klystron tubes in a controlled atmosphere. Localized heating plus the use of various alloys with progressively decreasing melting temperatures produce sound joints without affecting previously brazed joints. The absence of flux minimizes rejects

Brazing). Copper-gold alloys, such as Alloy 13, are used in sequential brazing of component parts for electron tubes, the operation also being conducted in a reducing atmosphere without flux (see Fig. 3). The aluminum-silicon alloy shown in Table 2 (No. 15) has been used to induction braze aluminum-alloy parts; however, the small temperature difference between the melting point of this alloy and that of the aluminum parts to be joined has severely limited induction brazing of aluminum alloys.

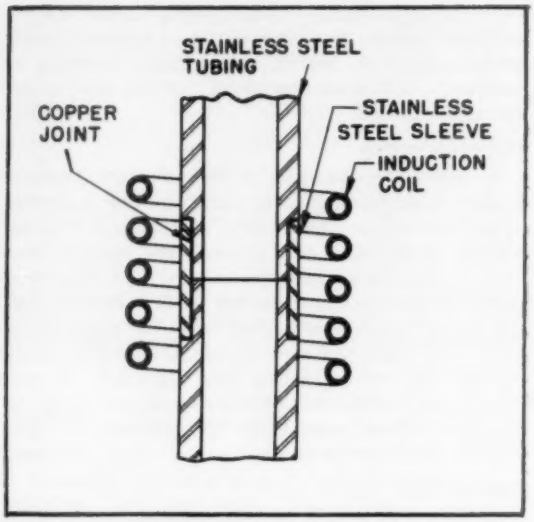


Fig. 4—Stainless-steel tubing and fittings for aircraft copper-brazed in controlled atmosphere. Reducing atmosphere provides sufficient surface cleansing at brazing temperature (2100° F) to allow uniform flow of copper into joint

As in the case of soldering, many of the brazing alloys are available in the form of wire, strip and powder. In addition, preforms of ductile alloys are commercially available in the shape of washers, rings, etc. Such preforms permit preassembly for automated operations and control the amount of alloy used, thus conserving alloy and producing uniform joints of good appearance. Powdered alloys have proved generally unsatisfactory.

In addition, brazing alloys are available as clad materials, i.e., as copper, clad on both sides with thin layers (0.0025 to 0.010 in.) of such alloys as Nos. 3 or 5. These clad alloys have been applied where the joint is subjected to considerable stress in use, or from contraction during cooling, i.e., in carbide-tipped tools.

Brazing Fluxes

Precleaning is no less important in brazing than in soldering. Surfaces to be brazed should be chemically cleaned to remove heat-treatment scale, corrosion products, grease, etc., prior to heating and the joint areas fluxed as soon as possible to avoid contamination from handling or exposure. It is interesting to note that brazed joints involving cast-iron parts are more dependably gas-tight and liquid-tight and have higher strength if the parts are electrolytically treated to remove graphitic carbon from the joining surfaces before fluxing and induction heating.

Fluxes containing fluorides and alkali salts, preferably potassium, are generally used for induction brazing, particularly with the silver-brazing

alloys. These fluxes, normally used in paste form, become fluid and active below 1100° F, protecting the metal surfaces to be joined, dissolving residual oxides and promoting better flow of the alloy upon melting. Since many of the fluxes commercially available for brazing are of a proprietary nature, it is most satisfactory to use the flux recommended by manufacturers for their specific alloy.

It is interesting to note that special fluxes have been developed to facilitate brazing in special cases. For example, the difficulties generally experienced in silver-alloy brazing leaded brass, and copper alloys containing silicon and aluminum when using general purpose fluoride fluxes, may be avoided by a proprietary aluminum-bronze flux. Likewise, special fluxes containing boron are very helpful in the brazing of alloys containing chromium and in brazing carbide tips. In some instances, aerosol wetting agents added to the flux have proved useful.

Brazing in Controlled Atmosphere

Recently, techniques have been developed for induction brazing in a reducing atmosphere to avoid the use of flux and thus the problems of thorough removal of flux residues. Figure 1 shows a two-station bell-jar unit used for controlled-atmosphere brazing. In this unit, a purified dry reducing gas, such as hydrogen, enters the bell-jar at the top, displaces the air and surrounds the part to be heated. Upon heating to elevated temperature, oxide films on the metal surfaces to be joined and on the joining alloy are reduced, permitting satisfactory flow of the alloy into the joint by capillary action, thus producing a good bond.

Figures 3 and 4 illustrate typical assemblies brazed in an atmosphere without flux. Figure 3 shows schematically a number of critical brazed joints required in the assembly of Klystron tubes. Sequential brazing, using brazing alloys of decreasing melting temperature, is necessary in this assembly. For example, assembly of certain Klystron tubes often starts with copper brazing at 2000° F. The next joint may be gold brazed at 1925° F. Silver-alloy brazes then follow with alloys of decreasing melting temperature at 1650°, 1475°, 1380° and 1295° F. In this way succeeding joints are brazed at progressively lower temperatures to prevent damage to previously completed joints. Elimination of flux avoids defective tubes caused by flux residue after brazing. Figure 4 illustrates copper brazing of stainless-steel aircraft fittings in a hydrogen atmosphere without the use of flux.

Joint Design

Soldered or brazed joints to be made by induction heating require special consideration of the heating pattern; the method of preplacing the joining alloy; the tolerances between mating parts; the thermal conductivity; and the expansion characteristics of the materials to be joined.

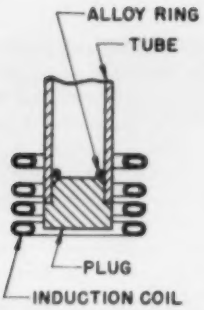
Several principles may serve as an aid in joint design. First, it is necessary that all areas adjacent to the joint are above the melting point of the joining alloy, preferably the whole joint area being at a uniform temperature. Furthermore, it is desirable to confine the heat to the joint area in such a way that this area arrives at the joining temperature first to avoid improper flow of alloy to higher-temperature areas away from the joint. Coil design is thus of paramount importance. Figures 5A to 5K show some coil designs used successfully in induction-soldering and -brazing applications.

Figures 5A to 5K also illustrate recommended positions for preplacement of the joining alloy. For best results, preforms of the brazing alloy should not form closed loops when subject to inductive coupling from the work coil. In addition, it is desirable wherever possible to electromagnetically shield the preplaced alloy with the components to be joined to avoid melting the alloy before the joint surfaces are at joining temperature. This can be done by placing the preforms inside the assembly, as in 5A, 5E, 5G and 5I; or by recessing a component as in 5F and 5H. Frequently, chamfers or grooves can be incorporated on one of the components to hold the preforms in place. Parts to be joined may be preassembled mechanically by spot welding, tab assembly or knurled press-fits to facilitate handling.

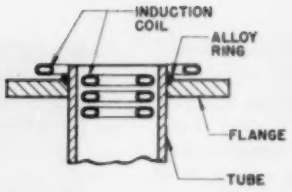
Soldering is used primarily for joining parts which are not highly stressed, and for sealing purposes. The strength of soldered joints varies considerably with such factors as the type joint, the properties of the metals being joined and the joint thickness. Short-time tensile strengths of tin-lead soldered joints have been reported from around 3700 psi to a maximum of approximately 6500 psi for the eutectic compositions. However, soldered joints lose strength rapidly as the temperature is increased. The thickness of the solder joint should preferably be about 0.003–0.005 in.

The influence of joint thickness and the strength of the component parts upon joint strength is particularly pronounced in brazing. A clearance of 0.0015 to 0.002 in. between parts to be joined by induction brazing is frequently recommended. Since the metal parts to be joined may expand at different rates, if differentially heated or if made of dissimilar materials, allowance should be made for differential expansion to assure the proper clearance when heated to the joining temperature.

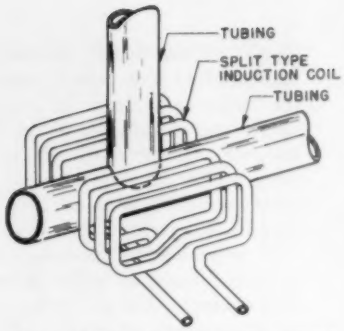
It is apparent that brazing designs should consider the strength of the brazed joint, i.e., a combination of the strength of the components being joined, and the strength of the joining alloy and the interfaces, rather than the strength of the joining alloy alone. Joint tensile strengths of low-carbon steel parts joined with silver-brazing alloys may be in the order of 50,000 to 60,000 psi. As may be noted in Figs. 5A to 5K, to achieve maximum strength, brazed and soldered joints should also be designed with large shear areas, rather than as butt joints.



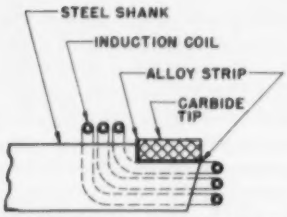
A. Plug-to-tube joint. Turns of solenoid coil may be spaced for suitable heat pattern depending upon the materials being joined. Tight fit desirable for maximum heat transfer



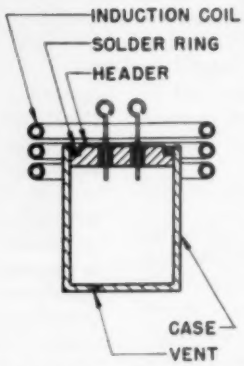
B. Flange-to-tube joint. Internal-external coil. Flange chamfered to hold preplaced alloy



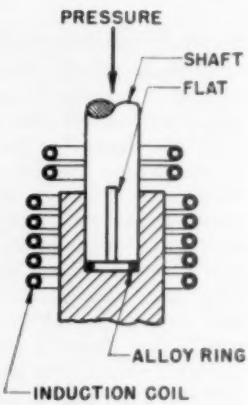
C. Tube-to-tube T joint. Split solenoid coil. Alloy ring preplaced internally to provide uniform fillet without excess joining alloy along the sides of the tube



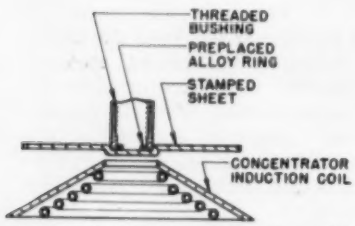
D. Joining carbide tips to shanks. Open-end coil. Alloy strip preplaced as shown



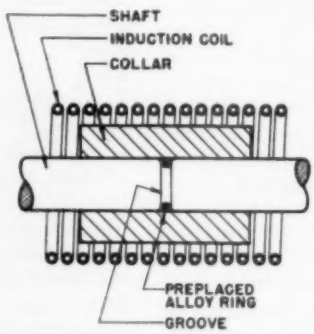
F. Header-to-case seal. Simple solenoid coil for uniform heating. Preplaced alloy recessed. Vent permits escape of expanded air to avoid leaky joint



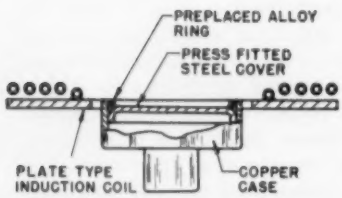
G. Shaft-to-fitting joint. Solenoid coil with varying diameter. Alloy preplaced internally at base of recess. Pressure used to seat shaft. Small flat permits escape of gases



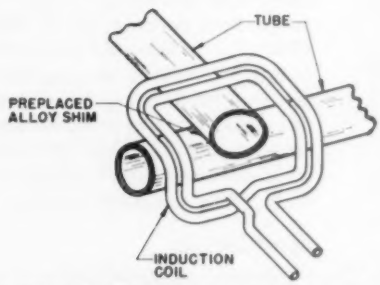
E. Threaded bushing joined to metal stamping. Concentrator coil localizes heat. Alloy preplaced at base of bushing



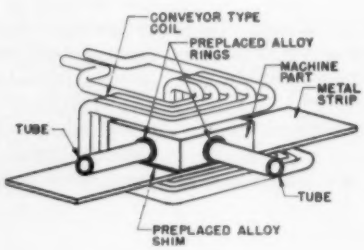
I. Shaft-to-collar joint. Solenoid coil. Alloy ring preplaced in machined groove



H. Assembly of formed metal shapes. Plate coil for localized heating. Alloy preform partially shielded from electro-magnetic field by case



J. Tube-to-tube joint. L-shaped pancake coil



K. Assembly of components. Conveyor-type coil. Alloy shim preplaced between machine part and metal strip. Alloy rings preplaced on tubes

Fig. 5—Typical joint and coil designs for nduction soldering and brazing

If possible, simple inspection of the joint should be considered in the preplacement of the joining alloy. This can be done in many instances by preplacing the joining alloy in such a way that it must flow into the joint by gravity and capillary attraction, showing uniform and complete penetration by appearance of the alloy at the opposite end of the joint.

Stress concentration and high residual stresses in the joint may be serious when the joint members are stronger than the brazing alloy and when differential contraction occurs as a result of joining dissimilar materials. The marked difference in linear coefficient of expansion between tungsten carbide (3.3×10^{-6}) and carbon steel (6.7×10^{-6}) may be particularly troublesome when the carbide is placed in tension, frequently resulting in cracking of the carbide. In such instances, a "sandwich" braze, utilizing a clad brazing strip, i.e., copper clad with silver-brazing alloy on both sides, is helpful. In such a braze, stresses are minimized as a result of plastic deformation in the low-yield-strength copper layer.

Selection of Induction-heating Generator

The generators required for induction soldering and brazing are generally small. This is because the temperatures required for joining are comparatively low, the volume of material heated is usually small and the rate of heating low to permit diffusion of heat throughout the joint area. Power densities of 0.5 to 1.5 kw/in.^{2} are common. Ultimately, the minimum size generator required for a given application is best determined by actual trial. However, an estimate of the size generator required may be made by a consideration of the power absorbed by the work, the power radiated from the heated piece, and the production rate required assuming good coil design and electrical matching between the generator and the work load. The power absorbed by the work is readily calculated from the relationship

$$P = \frac{(W)\ (\Delta T)\ (C)}{0.95(t)}\ \text{kw}$$

where

W = material heated, lb
ΔT = temperature rise, ° F
C = mean specific heat
t = heating time, sec, required to meet production requirements

In practice, it is difficult to estimate the weight of material heated in most soldering or brazing applications because heat is conducted away from the joint area, creating a temperature gradient for some distance beyond the induction-heated zone. Since the temperatures used in soldering and brazing are low, radiation losses are small and generally may be neglected in the preliminary estimate.

Actually, improper selection of power level is a frequent source of difficulty in induction brazing and soldering. Surprisingly, the difficulties encountered in the field are frequently traced to too rapid heating of the assembly. Very rapid heating prevents uniform temperature in the joint area especially when one of the materials being heated has poor thermal conductivity, such as stainless steel. This situation prevails particularly where the induction generator is used for a variety of applications, some requiring high power. It is extremely desirable to use generators with stepless, full-range power control, variable from practically zero to full output, and also having a tank coil with many taps permitting easy adaptation for coil connection directly to the tank circuit or through an electrical matching device.

Fixtures for Induction Joining

Fixtures used for induction soldering are generally similar to those used for brazing, though the lower temperatures associated with soldering permit some modifications, as described in the applications which follow. Since metal parts of the fixture may heat inductively if placed too close to the coil, nonmetallic materials are used extensively in fixture design. Nonmetallic materials used in induction heating fixtures include transite, glass-filled epoxy plastics, shaped and fired lava, and cast or machined ceramics. These materials vary considerably in their cost, ability to be machined or formed to shape, abrasion resistance and resistance to chemical attack from the flux. All are good insulators and have been used successfully.

Actually, metals are frequently used in the operating parts of the fixture. Nonferrous metals such as aluminum and brass are preferred in order to minimize heating by induction. If it is necessary to place metal parts of the fixture close to the coil, water cooling may be required. Closed metal loops in the fixture, coupled inductively to the induction-heating coil or leads are a common error in fixture design.

Induction-heating coils used in soldering or brazing are generally coated with a special material to protect them against spattered flux. Coils must be cleaned periodically in water to remove the flux preventing electrical shorting between turns.

Hand-operated induction soldering and brazing fixtures may be extremely simple and can often be designed by the user. However, induction soldering and brazing are highly adaptable to semiautomatic and automatic operations. Fixtures for mass production operations may become quite complex. Fortunately, work-handling equipment for automated operations has been developed and is available.

Many of the details of fixture design and work handling are presented in the applications which follow.

Induction-brazing Applications

Figure 6 shows a simple, hand-operated arrangement for brazing gold rings to settings with a gold-brazing alloy. The ring and setting are held in

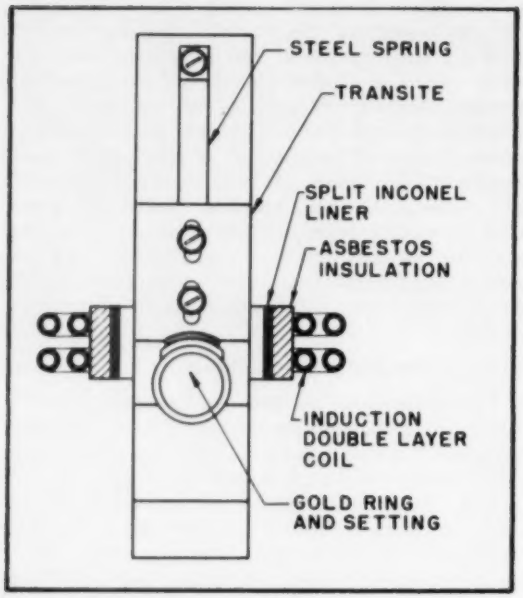


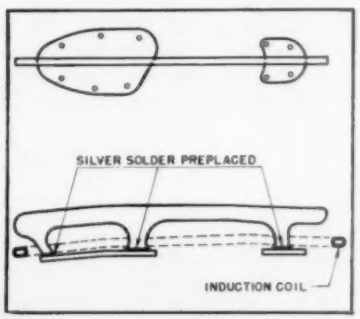
Fig. 6—Simple hand-operated fixture for brazing jewelry settings to gold rings by induction

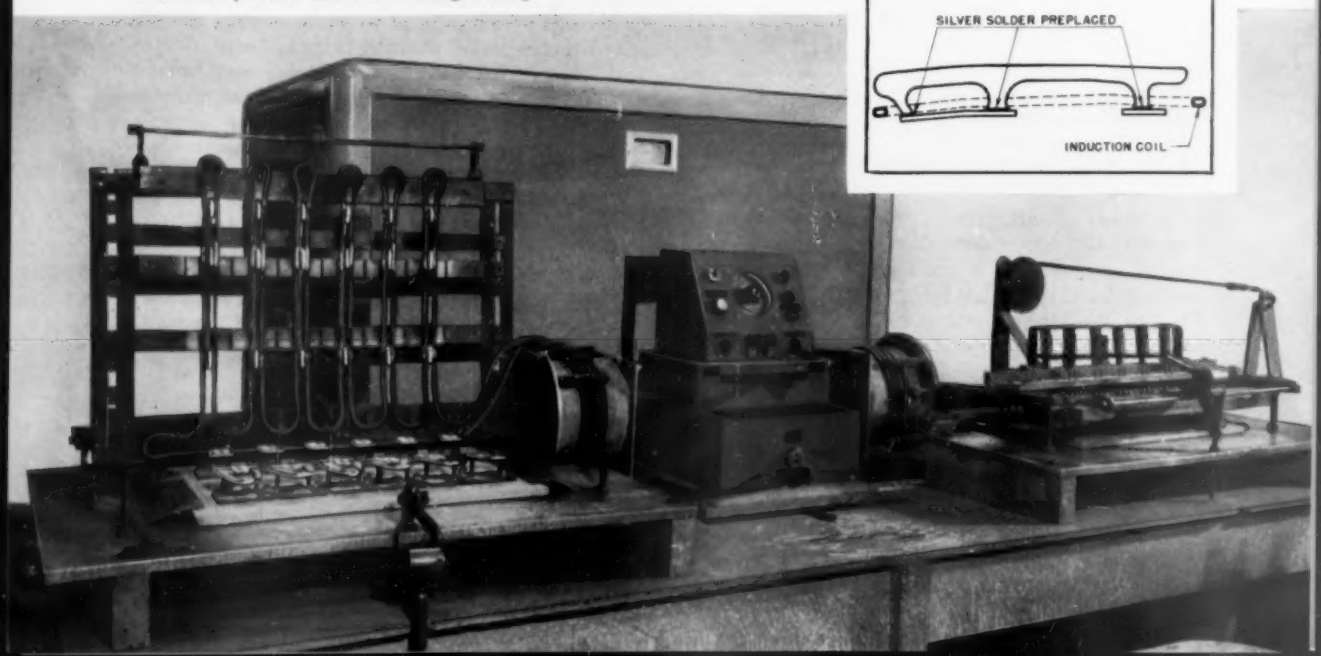
position by a spring-loaded fixture constructed of transite. Since transite is a nonconductor, the coil may surround the fixture as shown. Another interesting feature of this fixture is the use of a split metal liner surrounding the work but within the coil. In operation, the metal liner heats inductively to a temperature determined by its thickness, without, however, shielding the ring and setting assembly from the electromagnetic field of the induction coil. Thus the assembly to be brazed heats by both induction and radiation. This arrangement is desirable to effectively heat such thin sections as the ring settings.

A multiple fixture bar brazing six ice-skate assemblies simultaneously is shown in Fig. 7. In this arrangement, steel heel and toe plates are silver-alloy brazed to previously induction-hardened ice-skate runners. Localized heating prevents loss of hardness in the edge of the blade. For mass production, two multiposition fixtures are operated from a single induction generator, using a changeover switch. This arrangement provides essentially 100% duty cycle. Using the changeover switch, power is transferred from one multiposition fixture to the other upon completion of heating, permitting the operator to unload and reload the first fixture. This type of arrangement is useful where solidification time of the alloy is long or where relatively long heating times per assembly will limit production. It is one way to use generators of high power for successful brazing at a maximum rate of production. When the induction coils are very small, effective coupling may also suggest multiposition coil arrangements.

Induction brazing is also used extensively in the assembly of structural members. This is illustrated in Figs. 8 and 9. In Fig. 8, for example, sections of steel tubing are joined to form structural frames, using a split-type solenoid coil (see Fig. 5C). This type coil provides a uniform heat pattern in these complex sections and produces uniform, smooth fillets which require no further finishing. This type of application requires accurate dimensional

Fig. 7—Production arrangement for silver-alloy brazing of steel toe and heel plates to ice skate runners. Two multiposition fixtures are operated from a single induction generator using a changeover switch. Inset shows position of induction coil and preplaced brazing-alloy preforms. Fixture applies pressure to hold prefluxed components in contact during brazing





control between the mating parts of the joint.

Figure 9 illustrates the assembly of steel pulleys by silver-alloy brazing, using a unique fixture and coil arrangement. The coil for heating the bottom joint of each pulley is permanently coupled electromagnetically to the primary which is connected to the generator. The coil used for brazing the upper joint is pivoted to allow assembly of the pulley and preplacement of the brazing alloy, as shown. Upon completion of loading, the upper coils are swung back into the properly coupled heating position.

Figure 10 shows schematically an arrangement used for silver-alloy brazing of machined parts for flame-cutting torch assemblies by induction. Two operations are shown in the diagram, one involving a brazed joint between brass or stainless-steel tubes and a machined part at the top, and the other concerned with making four joints simultaneously to join the tubes and various machined components at the bottom. It is interesting to note the position of preplaced silver-alloy preforms, and the use of double-layer induction coils for heating. Relatively long heating cycles (38 sec) assure uniform heating throughout the joint area and therefore good brazed joints.

Wave-guide assemblies for the electronic industry are precision joined by induction brazing. Figure 11 illustrates the use of precision ceramic arbors accurately ground ($\pm$ 0.0002) to permit assembly of the flexible hose and machined flange without prohibitive misalignment. Since the ceramic is a nonconductor, it is not heated appreciably in service, thus minimizing size change and distortion. Excellent resistance of the arbors to wear and to wetting by the molten brazing alloy, as well as resistance to deterioration by flux, insures long service. An

Fig. 8—Typical brazed joints on structural members

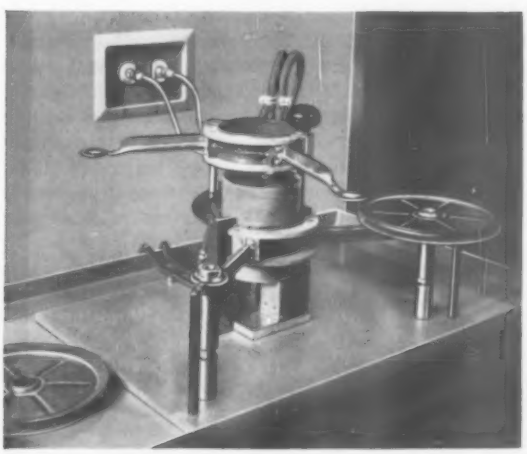


Fig. 9—Unique fixture and coil arrangement for assembly of steel pulleys by silver-alloy brazing

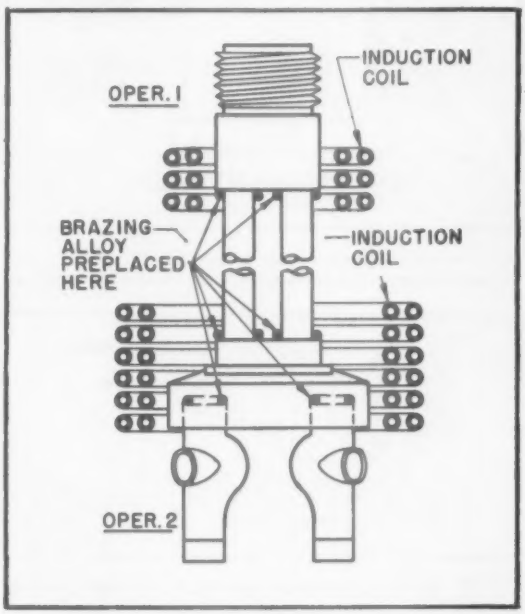


Fig. 10—Components of cutting torch assembled by induction brazing in two operations with double-layer induction coils. Silver alloy preplaced as shown

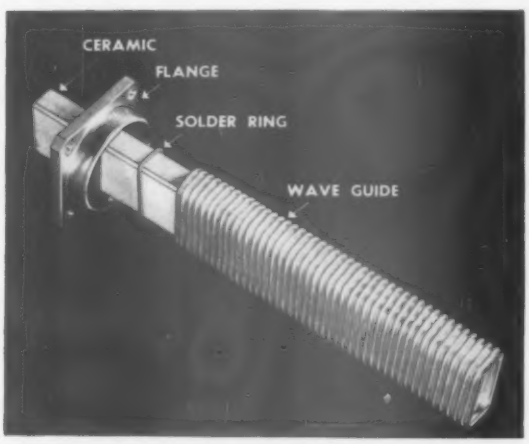


Fig. 11—Precision ceramic arbors aid in accurate assembly of wave guides by induction brazing

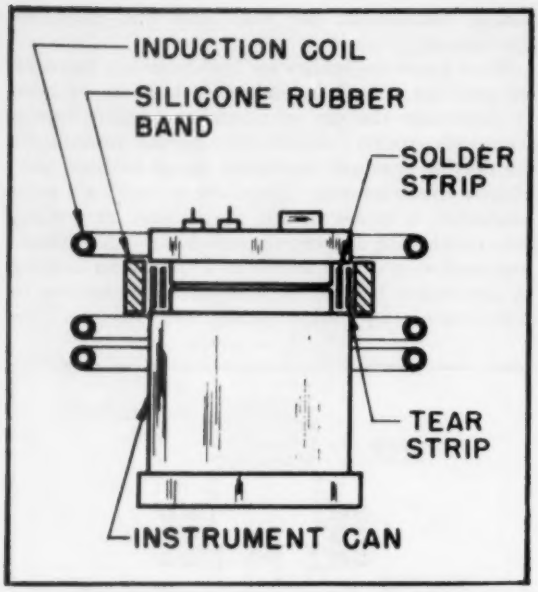


Fig. 12—Use of silicone-rubber bands to facilitate induction soldering of instrument cases with a tear strip

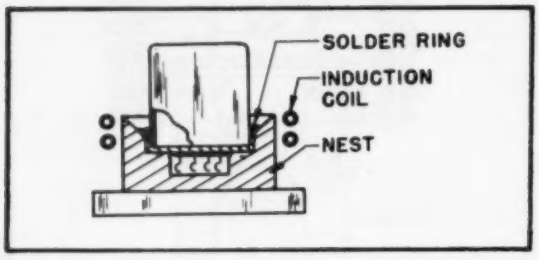


Fig. 13—Melamine or silicone fibreglass laminate "nests" aid in induction soldering assemblies where the solder preform is difficult to hold in place. Nests also permit alignment of components for joining if preassembly is inconvenient

interesting aspect of this operation is the ease of inspection. The molten brazing alloy drawn into the tube-flange joint, appears at the bottom of the flange, signifying adequate flow. A uniform small fillet remains at the top of the flange.

Induction-soldering Applications

Since the temperatures required for induction soldering are lower than those required for brazing, deterioration of the fixtures from constant reheating is relatively less. Furthermore, parts to be soldered may be held in position by techniques which are unsatisfactory in induction brazing. Figures 12 and 13 illustrate two techniques especially adaptable to induction soldering.

Figure 12 schematically illustrates the use of silicone rubber bands to hold the components of cans with a tear strip in position throughout the induction-soldering cycle, thus assuring proper positioning. The rubber bands are reusable for

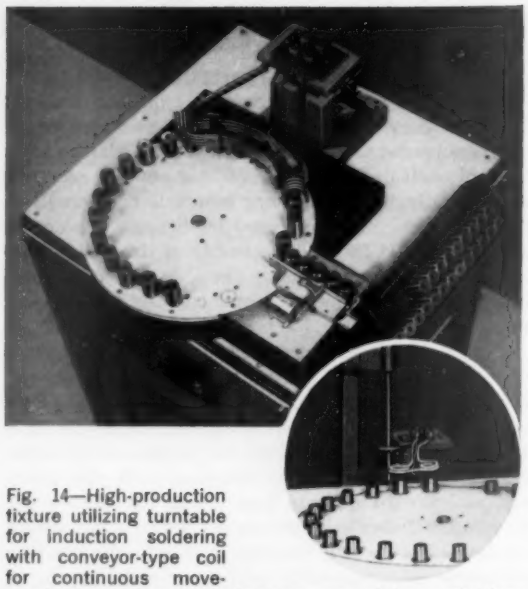


Fig. 14—High-production fixture utilizing turntable for induction soldering with conveyor-type coil for continuous movement. Inset shows indexing arrangement for applications where localized heating is required

many cycles, the life depending upon the degree of stretch and the temperature. Turns of the induction coil are separated as illustrated, to insure heating of the header and case components without overheating the tear strip. Venting allows air expansion during heating to avoid "gassing" through the joint.

Figure 13 illustrates the use of melamine or silicone fibreglass laminate materials for "nests" to help position the solder preforms and the parts of the condenser cans to be induction soldered. The small "nest" is designed to fit into the coil and to provide proper positioning of the parts to be joined. In practice, the nest should be closely fitted to the contour of the case. Since the "nest" material is chemically resistant to the flux, it may be cleaned periodically and used for extended periods of time. Several "nests" may, of course, be used in the construction of multiple-position fixtures.

Induction-soldering applications requiring high production frequently use an arrangement of a turntable and a conveyor-type coil, as shown in Fig. 14. In this setup, the parts to be joined after proper positioning and preplacement of the solder and flux are moved through the conveyor coil at the proper speed, to bring the joint area to soldering temperature. This basic-type fixture may also be used with an indexing arrangement in instances where the heating must be more localized. The inset in Fig. 14 shows the coil arrangement for soldering capacitor cans. The induction coil shown is raised to allow the table containing preassembled components to bring two new assemblies into soldering position; the coil then descends into heating position. Localized heating prevents damage to the components of the capacitor.

Fig. 15 shows a multiple-position fixture for induction soldering four assemblies simultaneously.

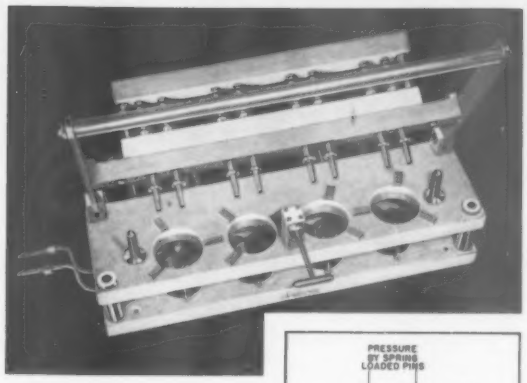


Fig. 15—Multiiple-position fixture using pressure pads to insure proper positioning of component parts during induction soldering. Schematic drawing illustrates position of induction coil and solder ring

The operation involved is shown in the inset. This application is of interest, since pressure is utilized to force the tube into proper position in the flange when the preplaced solder preform melts. Pressure is applied through the spring-loaded pins which contact the tube when the top section of the fixture is closed into position.

Soldering Operations in the Electrical Industry

Figures 16 and 17 present some new and interesting applications. Fig. 16, for example, shows an arrangement for soldering progressively numerous metal terminals to printed electrical circuits by induction heating. The printed circuit, with its thin metal film placed in the coil with proper orientation does not heat sufficiently to cause peeling of the metal film from the base. Preplacement of the solder and progressive movement of the terminal board through the coil speed up production by eliminating individual handling.

A simple arrangement for opening hermetically sealed instruments for servicing is shown in Fig. 17. Induction heating, using a double-layer coil, produces localized heat at the solder joint, melting the solder and allowing removal of the metal cover. Rapid localized heating prevents damage to the instrument. After servicing, instrument cases may be resoldered with the same setup. This application has proved particularly valuable at aircraft-servicing depots.

Conclusion

The applications of induction soldering and brazing extend to almost every industry concerned with metal fabrication. Frequently, the unique characteristics of this method, such as very localized and rapid heating, permit soldering or brazing of assemblies which would otherwise be impractical. Induction soldering and brazing are ideal for production-line operation because of their adaptability to automation.

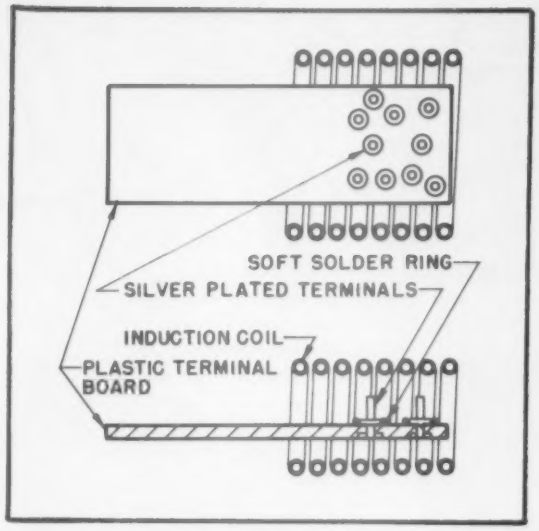


Fig. 16—Arrangement used for joining terminals to printed circuits by induction heating. Terminal board with prefluxed and preplaced solder rings is moved progressively through the induction coil

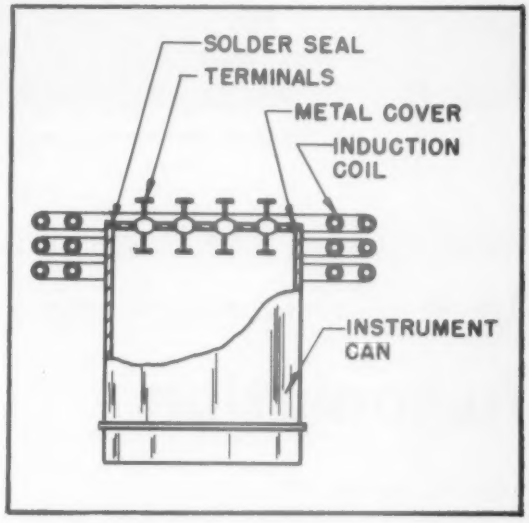


Fig. 17—Rapid heating allows opening and resealing of instrument cases for servicing without damage to internal parts. Glass-metal terminals have been previously soldered to cover by induction

Recent and continuing developments in soldering and brazing, including fluxless soldering, controlled-atmosphere brazing, improved coil design, and new joining alloys, flux, and fixture materials, are extending the use of induction heating to many new industrial applications.

Acknowledgment

The authors wish to thank the Sperry-Rand Corp. for supplying Figs. 1 and 3, and St. Lawrence Manufacturing Co. for Fig. 7.

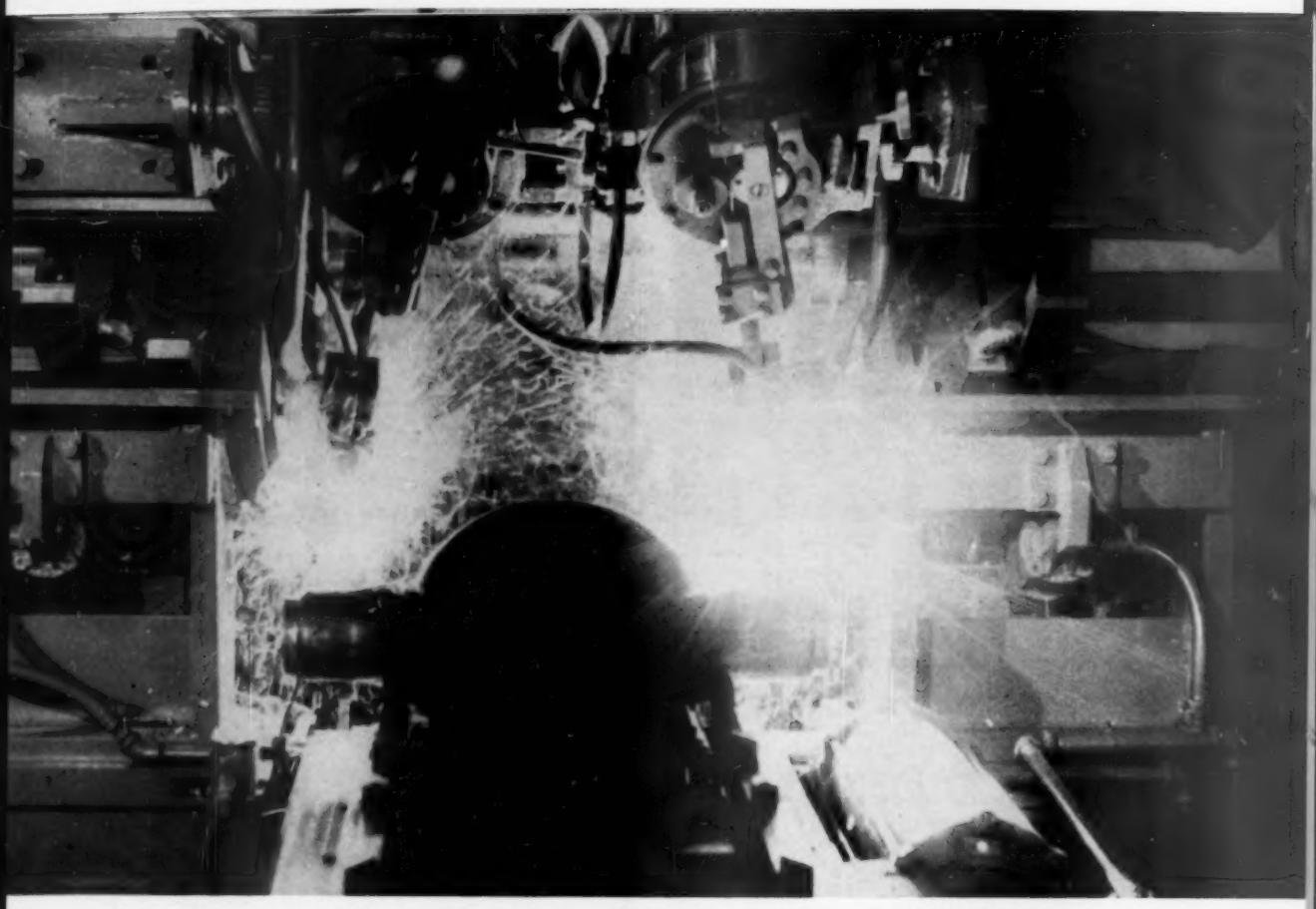


Fig. 1—A view of a completely automated rear-axle-assembly operation using the consumable CO_2-shielded process

Continuous research and development in the field of metals joining extend the use of

Arc Welding Processes and Equipment for Automation

BY F. E. ADAMSON

SYNOPSIS. While automatic welding processes have been available for years, new techniques developed in the last few years have widened the scope of arc welding in automation. The highly mechanized automotive industry has attained the greatest refinement in the application of these developments. Six processes cover most of the automated operations. These are: (1) submerged-arc process; (2) inert-gas-shielded tungsten-arc process; (3) inert-gas-shielded metal-arc reverse-polarity process; (4) inert-gas-shielded metal-arc straight-polarity process; (5) CO_2-shielded metal-arc process; (6) improved CO_2-shielded process.

In addition there are two general methods for controlling arc conditions. These are the arc-voltage-regulating and the constant-potential methods. Each process and arc-control method has certain advantages and disadvantages to be considered in their application to automation.

This paper is a comparison of the six processes and two arc-control methods as related to automation. A brief description of the development which led to the latest processes is presented. The application of each process as part of a complete arc-welding machine and the advantage of the process for the particular application is described and illustrated.

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Introduction

Recent process developments make arc welding well suited for automation in a great variety of industries. Automated arc welding is now a very practical answer to rising labor and material costs.

Actually the metalworking industry is on the threshold of a new era. The first step was accomplished through improved welding processes and the versatile fixturing needed to completely automate these new concepts. The progress made to date is evident on a number of lines, wherever high-production mild-steel or aluminum welding is a necessity—housings of all sorts, rollers, stator cores, axles, clutches, frames, tubular pieces, transformer tanks, air-moving equipment—applications too numerous to mention. The common denominator is the requirement for a sound weld of good appearance, and consistent quality at a minimum cost on economical lots of repetitive parts.

Of the industries using arc welding extensively, the automotive is certainly the most highly automated. Moreover, each year significant new advances are made to extend this condition. Along with improvements in other manufacturing methods, arc-welding technology has also improved. Some arc-welding operations have been automatic for 25 years; however, few can be classed as fully automated. Considerable development in processes, equipment and fixturing is still to be accomplished before full automation is achieved in the use of arc welding.

The first large-scale installation of automatic arc-welding equipment was made in 1925 when automotive parts formerly made of wood and castings were redesigned for automatic welding.[1] Universal joints were welded to drive shafts on a machine with a production rate of 45 to 70 assemblies per hour. Two simultaneous welds, one at each end, completed the shaft in 30 sec. Although the welding machine, the automatic equipment and the fixturing have changed, the same basic ideas are still being used today.

Since the first application of automatic welding to the production line, various methods and processes have been used. These include, in general, the bare-wire metal-arc process, the shielded metal-arc process, the flux-cored-wire process, the submerged-arc process and the gas-shielded process.

The original bare-wire metal-arc process was soon discarded because of poor physical properties caused by porosity in the weld metal. The shielded metal-arc process used a continuous electrode with coatings similar to manual electrode formulations. While the arc characteristics were good, the problem of conducting current into the core wire was troublesome, and the process did not achieve widespread use. This problem was solved with the development of flux-cored electrodes which were used for a number of years for hard surfacing and are now finding increased usage for mild-steel welding. As yet the process has not been applied extensively to automotive production because of high electrode costs and the need for slag removal.

Submerged-arc and gas-shielded processes make up the bulk of automatic welding today. The gas-shielded processes cover a wide range of methods but, in general, can be divided into inert-gas-shielded tungsten-arc, inert-gas-shielded metal-arc (consumable-electrode), and CO_2-shielded metal-arc (consumable-electrode) process.

This paper will describe some of these processes, mainly in connection with mild-steel welding since this constitutes the majority of automatic or automated welding done today.

Submerged-arc Process

Many applications use the submerged-arc process because of its ability to produce a high-quality weld at high speed and low cost. It has a particular advantage on heavy weldments where the deposition rate may be as high as 80 lb per hr; however, the process is also usable on materials as thin as $^1/_{16}$ in. where welds of good quality can be made at speeds of 100 to 150 ipm.

Submerged-arc welding has found wide acceptance as an automatic welding process, but the granular flux used to shield the arc gives rise to a number of problems which have made automation of the process very difficult. These problems include: (1) flux handling; (2) flux removal; (3) arc starting; (4) overlapping; (5) holding of flux on rounds; (6) abrasive action on all mechanical parts.

Some of these have been solved but, in most cases, the solutions have been complicated. Many of the problems are basic with the process. Therefore, many of the large-scale automated or semi-automated welding systems installed in the past three or four years have used gas-shielded processes wherever possible.

Inert-gas-shielded Tungsten-arc Process

The aristocrat of the welding methods common in industry is the inert-gas-shielded tungsten-arc process. Although it is not always the most practical process from a cost standpoint, it is the most versatile. Almost any known metal and even combinations of metals can be welded in practically any position. Several features of the process make it particularly adaptable to automation. Arc starting, initiated by high frequency, is almost foolproof. The complete absence of spatter and flux eliminates many of the problems found in other welding processes where these materials impair operation of the fixture. When applied without filler rod, the mechanical wire-drive problems encountered in other processes do not exist. In spite of these advantages, the process is limited to light-gage assemblies with good fitup. Accessory equipment can be added for feeding filler metal into the arc, but the deposition rate makes the process uneconomical compared to the consumable-electrode processes.

Inert-gas-shielded tungsten-arc spot welding plays an important part in the assembly of thin sheet-metal parts. These arc-spot welding operations are among the few completely automated arc-welding processes in existence today. The need for an operator is more in the area of maintenance to adjust electrodes from time to time.

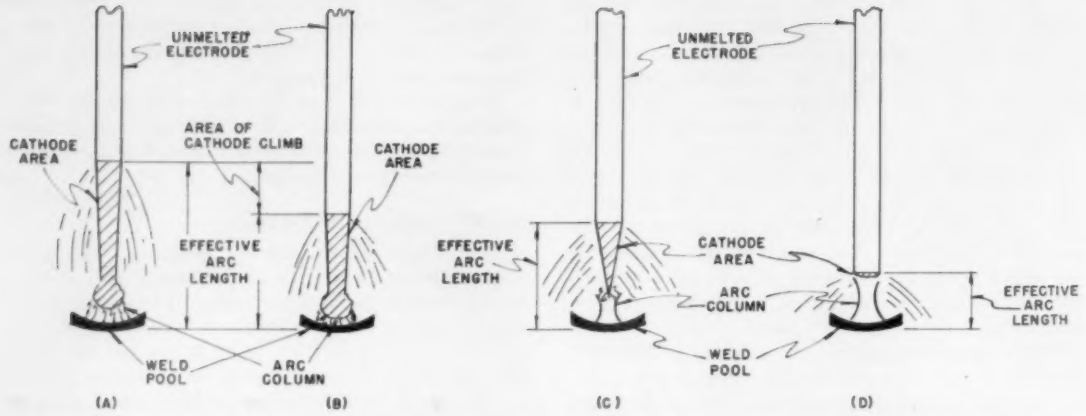


Fig. 2—Appearances of arcs and cathode areas of electrodes for various welding conditions. (A) and (B) illustrate the extremes of cathode area and effective arc length that occur with unstabilized bare electrode operated DCSP in pure argon; (C) bare electrode operated DCSP in argon containing 5% oxygen; (D) stabilized covered electrode operated DCSP in pure argon

Inert-gas-shielded Metal-arc Process

Reverse Polarity

The development of inert-gas-shielded metal-arc (or consumable-electrode) welding was a major technological advance in welding methods for automation. Many of the costly disadvantages of

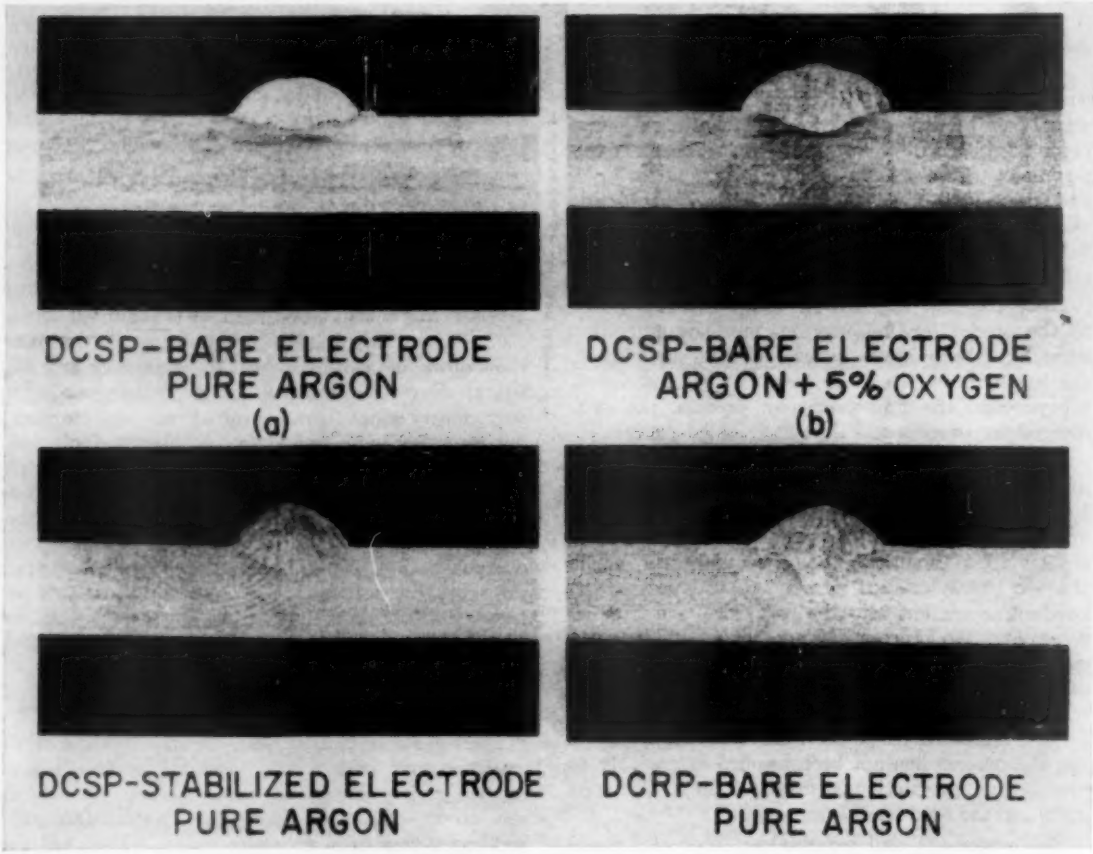


Fig. 3—Macrographs showing relative penetration patterns in $^1/_4$-in. mild-steel plate for steel electrode in atmospheres of pure argon and argon-oxygen mixtures. Current, 360 amp; travel speed, 30 ipm

earlier consumable-electrode processes were eliminated. Gas shielding made the weld zone completely visible and eliminated slag removal. On many applications, where complete analyses of costs were made, including the applicable elements such as fixture wear, flux loss, flux handling time and cleaning time, the later consumable-electrode process indicated a distinct advantage over earlier consumable-electrode welding processes.

While both argon and helium have been used for shielding, argon finds much wider application because of superior arc characteristics. Since argon is a heavier gas, it forms a better shield than helium in the downhand welding position where most automatic welds are performed. Also, the use of helium is limited by its importance in national defense. Since the United States is the only country with helium deposits, its use is closely controlled to prevent depletion of reserves.

As with tungsten-arc welding, this process can be used on a wide variety of materials. First introduced for aluminum and magnesium, its excellent performance led to consideration of the process for steel. However, a mild-steel wire with pure-argon shielding showed a tendency toward arc instability resulting in porosity and spatter. This deficiency was overcome by the addition of oxygen to the argon shielding gas. Oxygen additions not only increase stability but produce a weld with better bead contour and better wash; although the bead surface is slightly oxidized.

The consumable-electrode process was another major breakthrough toward a trouble-free welding method. The absence of flux insures good starting without the need for high frequency, reduced fixture wear, and eliminates interpass cleaning. It overcomes the difficulties encountered with the submerged-arc process where flux falls away from small-diameter parts. Little or no spatter develops to clog gas passages and jam fixtures when arc conditions are properly adjusted. Its reliable operation solves many of the problems which hinder the automation of arc-welding processes.

Straight Polarity

In 1954, an inert-gas-shielded metal-arc process using straight polarity with argon and a lightly coated wire for mild steel was announced.[2] This now constant-potential process was the result of years of research in arc physics. The study covered the field of temperature gradient within the arc, effects of elements and compounds injected into the arc, shielding-gas mixtures and bare electrodes at straight polarity in argon. Impetus for the study was the inherent high burn-off rate of steel wire in argon when using straight polarity. Comparison between straight and reverse polarity showed a burn-off rate of 1.8 times higher for straight polarity. However, other characteristics prevented its use. The arc was relatively unstable and had an arc "umbrella" extending far up the side of the wire. Figure 2 illustrates the configuration of various inert-gas-shielded arcs. Instability caused by the arc wandering over the work disrupted the flow of shielding gas.[2] This changed the flow from laminar to turbulent and appreciable amounts of air were drawn into the arc. In addition, the straight-polarity arc produced a poor bead shape with shallow penetration and very little wetting of the base plate.

Research studies indicated that addition of certain metallic oxides to the surface of the wire could stabilize the arc. These additions definitely fix the arc to a localized area at the end of the electrode. In addition to increasing stability, the coating increases penetration by controlling the distribution of energy between electrode and work. Figure 3 shows a comparison between penetration and bead shape for various inert-gas-shielded consumable-electrode processes.

Welds made with the straight-polarity process are sound and porosity-free with physical properties as shown in Table 1. The deposition rate is 25% greater than with the reverse-polarity consumable-electrode process. Increased deposition allows higher travel speeds for a given weld size and reduces the welding cost. It has only slightly less penetration than the reverse-polarity consumable-electrode process. A weld at straight polarity has a relatively wide flat bead which is particularly advantageous on parts where fit-up cannot be held to close tolerances.

CO_2-shielded Metal-arc Process

The latest development in automatic arc welding to come into larger-scale use is the CO_2 process for mild steel. This is inherently a low-cost, high-deposition, high-penetration method. Original attempts to use the process ended in failure because of porosity and the narrow-bead characteristic. These early failures were caused by improper electrode chemistry and the lack of moisture-free shielding gas.

Research studies led to a comparison between the metal deposited by the CO_2 process and the metal deposited by the inert-gas-shielded metal-arc process. The chemistry of the deposited metal with an inert-gas shield is very close to the chemistry of the core wire, but considerable burnout of elements occurs in a CO_2-shielded weld. The intense heat of the arc dissociates the CO_2 into CO and O_2. The free oxygen combines with all elements as the core wire transfers through the arc. Deoxidizers pre-

Table 1—Weld-metal Physical Properties

Temperature, ° F →	+80	0	−100	−200
Yield point, psi	63,200	81,700	90,000	109,200
Tensile strength, psi	76,000	92,400	100,600	111,500
Elongation, % in 2 in.	27.9	25.85	25.50	27.13
Reduction in area, %	69.4	69.90	61.30	57.90
Impact,* gas metal-arc, DCSP ft-lb	100.0	80.0	22.0	...
Impact,* E6020 manual, ft-lb	58	25	21.0	...

*V-notch Charpy impact test.

vent porosity by limiting the carbon-oxygen reaction in the molten pool and as the metal transfers across the arc. They must transfer in sufficient strength to be effective. This investigation led to larger deoxidizer additions to make up for the oxidizing effect of the shielding gas. The addition of deoxidizers is limited since their effect on the deposited metal is similar but not equal to the effect of adding carbon, i.e., a reduction in ductility and an increase in tensile strength.

Even larger deoxidizer additions have been made to allow operation at higher arc voltages. An increase in arc voltage will increase the bead width and lengthen the arc. A longer arc exposes more of the arc column to the shielding gas and causes greater burnout of elements. Aluminum-killed wire (along with manganese and silicon) has sufficient deoxidizers to overcome the effects of greater burnout.

With an extremely low-cost shielding gas and a high welding speed, the CO_2 process has shown large cost reductions over other joining methods when properly applied. Gas consumption becomes a minor factor at flow rates of 35 cfh and a cost of $0.01 to $0.02 per cu ft. In addition to its cost advantage, the process deposits a sound weld with physicals equal to or better than other mild-steel processes.

To take full advantage of the CO_2 process, uniform parts are required and fixturing must place the end of the electrode within half the electrode diameter of the joint. This is especially important with drawn sheet-steel parts.

Improved CO_2-shielded Process

The usual CO_2-shielded process operates in what might be called the spray-transfer range. For example, a $^1/_{16}$-in. diam electrode has a spray transfer range of 300 to 600 amp at an arc voltage in the order of 25 v. Within this range, the arc is relatively stable and spatter losses account for around 12 to 14% of the electrode burnoff. Due to the inherent penetration of the CO_2-shielded arc, the minimum plate thickness for a lap-fillet weld, for example, is about $^3/_{32}$ in. This operation would be at 300 amp with a travel speed of 120 ipm. For certain applications where the weld is positioned, fixturing is precise and part fit-up is good, travel speeds may be increased using higher currents. If the current is reduced below 300 amp to reduce penetration, excessive spatter and poor arc action results. The high minimum current required for good arc action was a limitation of the CO_2-shielded process until recently.

The first step toward improving the CO_2-shielded arc was to learn more about its characteristics. The two most useful tools for such investigation were high-speed photography (7000 frames per second) and oscillograms. As a comparison, these tools were used to record data not only for an arc in CO_2 but for arcs in pure argon and argon with various mixtures of CO_2. Both instruments revealed the extremely smooth transfer of molten metal through the pure-argon arc. As CO_2 was added, the arc began to shorten and became more violent. High-speed photography clearly demonstrated the development of spatter. With a shorter arc, the molten drop on the end of the electrode was closer to the weld puddle and occasionally bridged across the arc, shorting the electrode. Since the power supply for a constant-potential system can produce high short-circuit currents, surge current resulting from the short literally disintegrated the droplet. High-speed color photography showed the droplet exploding and floating off in all directions. Oscillograms served to confirm the photographic results by showing the extremely high surge currents present in the system.

In an effort to eliminate the spatter problem at low current, experiments were directed toward coating the wire with ionizers to lengthen the arc and, in this way, reduce electrical shorts. This experimentation was somewhat successful in improving arc action, but far greater results were derived by consideration of the electrical circuit alone.

The reduction of surge currents appeared to be entirely feasible by the addition of a reactor to the welding circuit. To prove the theories, comparison tests were made with and without the addition. Operation with a reactor of the proper inductance showed phenomenal results in the reduction of spatter and the ability to stabilize the arc at low currents. The proper inductance was found to be dependent not only on the total inductance but also on the proper selection of the operating point on the saturation curve.

The resulting arc, in appearance and sound, at first seems to be extremely erratic. A properly adjusted arc has a sound similar to a motor-boat engine. Investigation of the new CO_2-shielded arc shows the repetitive sound to be a result of a series of short circuits between electrode and weld pool. The molten drop on the end of the electrode touches the puddle, shorts out and is forced into the molten pool by magnetic pinch effect. While the arc is shorted, the reactor allows time for the droplet to clear before the current can reach a value which would cause it to disintegrate. An inductive voltage developed between the electrode and the puddle, as the droplet clears, insures arc restarting. Thus the reactor not only limits peak currents during an arc short but also helps to re-establish the arc after the short has cleared.

The addition of the proper inductance to the welding circuit has opened new fields to CO_2-shielded and inert-gas-shielded consumable-electrode welding. The minimum operating current for any given wire diameter has been reduced to less than half the operable value without the reactor. It allows the substitution of a large electrode for a small electrode at a reduction in wire cost. It is possible on some applications, for example, to replace an 0.040-in. wire with an 0.091-in. wire and still weld at the same current. This has also ex-

panded the application of the process to thinner materials. Where the minimum plate thickness for a $^1/_{16}$-in. diam electrode was about $^3/_{32}$ in., the new minimum plate thickness for the same electrode is about 0.047 in. for a fully automatic weld. The addition of a reactor to the circuit has opened a wide range of sheet-metal applications to CO_2-shielded welding. Similar joints are now possible with argon shielding on other common ferrous and nonferrous metals.

Another new field opened by the use of the reactor is all-position welding for mild and stainless steel. The CO_2-shielded consumable-electrode processes have been used successfully on automatic welds in the vertical-down position. Vertical-up and overhead welding is now possible with the proper inductance in the circuit, since extremely low currents reduce the size of the weld puddle. With a small puddle, surface tension overcomes gravity, and the metal stays in place. This new method has made out-of-position welding practical with gas-shielded metal-arc welding.

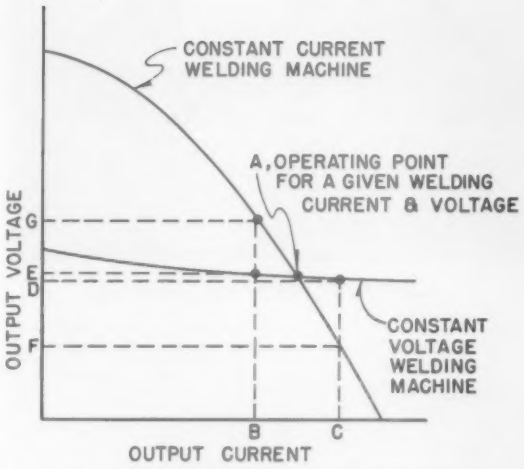


Fig. 4—Output characteristics of the constant-current and constant-potential welding machines showing a comparison in the change in output voltage with a change in arc current

Equipment

The application of any welding process to automation requires consideration of the systems employed and their advantages and disadvantages. For optimum results, the system should be a package designed to coordinate the functions of welding equipment, welding fixture and process. This approach can make the best use of the advantages and minimize the limitations of a process.

Automatic welding equipment for the consumable processes is designed to use either of two methods for control of arc conditions: the arc-voltage regulating method or the constant-potential method. Equipment for the earliest automatic processes used the arc-voltage regulating method with a conventional constant-current direct-current machine. With this method, arc voltage or arc length is a function of the wire-drive speed.

The wire-drive motor is a shunt or series-wound direct-current motor. In order to maintain constant arc length, the speed of the electrode-drive motor must be controlled by arc voltage. If the arc voltage is too high, the motor speed must increase to shorten the arc and return the system to equilibrium. A low arc voltage must cause the motor to drop in speed.

Speed of response or the ability of the system to correct rapidly for disturbances varies according to the control method employed. The simplest and least responsive control is a system where the wire-drive motor is connected directly across the arc. This arrangement can never completely correct disturbances caused by increased motor loading since part of the change in arc voltage is lost in increased armature-resistance drop.

The more refined systems compare the arc voltage with a preset reference voltage. The difference between the voltages is applied to the drive-motor armature through an electronic, magnetic or rotating amplifier. This method of control leads to higher sensitivity with arc voltage held within narrower limits. However, the possibility of oversensitivity may lead to instability and hunting in the control system.

The constant-potential method developed in 1953 uses a constant-potential welding machine with an adjustable-speed wire-drive system. While the speed is adjustable, at any particular setting it is substantially constant from no load to full load. The constant-speed control may use a governor-type motor or a more exact electronic motor control with a load compensator.

The constant-potential welding machine has an adjustable output voltage but, at any particular setting, the voltage is relatively constant from no load to full load. The arc current is preset by choosing the wire-drive speed. The output characteristics of the constant-current and the constant-potential welding machines are shown in Fig. 4. Within their operating range, either welding machine can develop the same output voltage and current for a particular set of arc conditions. This is indicated by the intersection of the curves at point *A*. Changes in arc conditions which might cause the arc current to vary between points *B* and *C* will cause the output voltage of the constant-potential welding machine to fluctuate between points *D* and *E*. For the change in current, there is a slight variation in output voltage. However, the same change in arc current will cause the output voltage of the constant-current welding machine to fluctuate from *F* to *G*. Thus, a change in arc current will cause a wide variation in the output voltage of the constant-current welding machine. Since the output voltage is nearly the same as the arc voltage, this variation is reflected to the arc.

The relatively fast response of the constant-po-

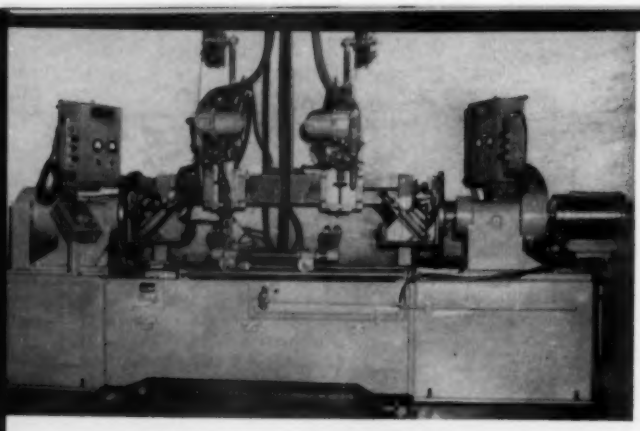


Fig. 5—An automatic fixture for the submerged-arc welding of truck axles

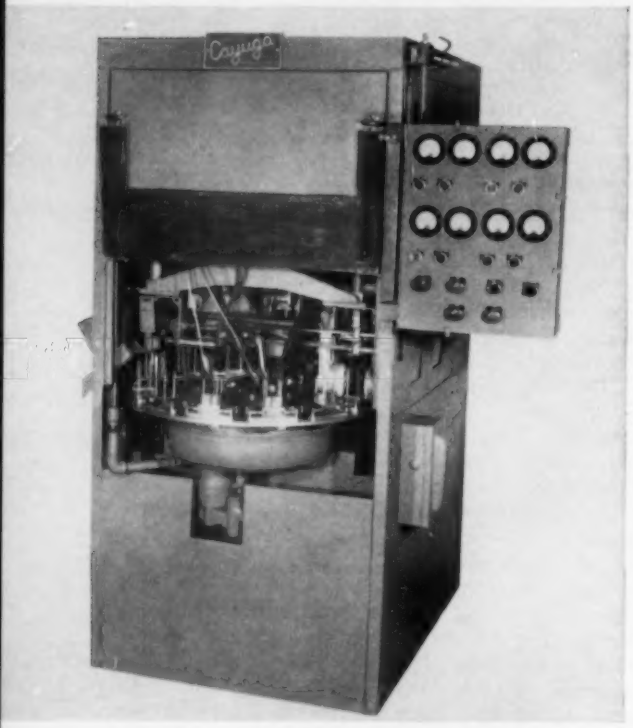
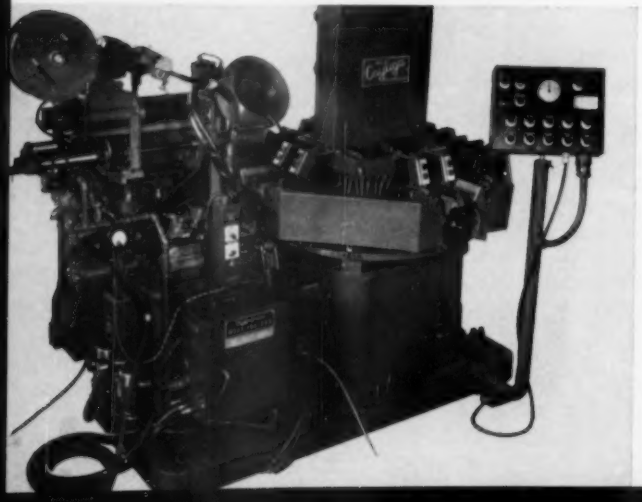


Fig. 6—A machine for the automatic assembly of a small motor stator by the inert-gas tungsten-arc process

Fig. 7—An arc-welding and machining fixture using the inert-gas metal-arc process for welding small motor frames and cores

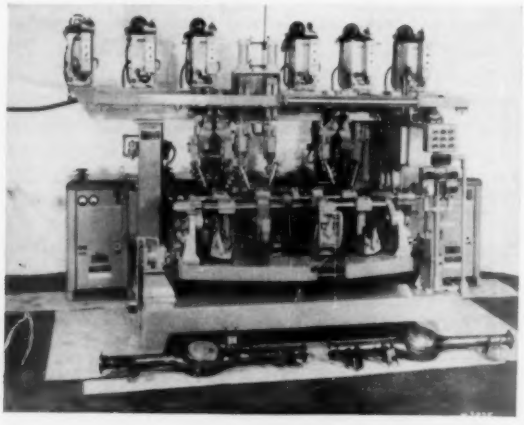


tential system is obvious when the two methods are compared. With the arc-voltage regulating control, the change in wire-drive speed necessary to correct a change in arc voltage may require an appreciable part of a second. This is due to the mechanical inertia of the wire-drive system. A change in the output current of a constant-potential rectifier welding machine requires $^1/_6$ of a cycle—$^1/_{360}$ sec.

Consider, for example, an inert-gas-shielded metal-arc welding operation using 0.040-in. diam electrode wire. At 400 amp, the electrode speed is on the order of 600 ipm, or 10 ips. Assume that the force required to drive the electrode increases due to a change in the position of the torch as it moves along the seam. Also, assume that the extra loading would cause a 10% drop in motor speed, and the system has no corrective means. One inch of electrode is lost per second. However, the arc-voltage regulating control does have means for correction but, due to the inertia of the system, correction lags by $^1/_4$ sec. In the time required for correction, the arc has lengthened by $^1/_8$ in., and the wire is very probably melted into the torch. In comparison, the constant-potential control will now allow the wire-feed speed to change appreciably if the circuit includes load compensation. If the speed does drop by 10%, the welding machine will hold the arc voltage relatively constant, but the arc current will change after $^1/_{360}$ in. of electrode is lost.

Both of the control methods described are used today. The arc-voltage regulating control has the advantage of low first cost but lacks the ability to control the voltage effectively and maintain stability. Poor stability is more pronounced at the high wire-drive speeds required for small electrode wire. Starting problems, due to the limited short circuit current of the constant-current welding machine, are common. Occasionally, the electrode wire will fuse to the work at the start of a weld. Also, an

Fig. 8—A rear-axle welding fixture for welding control arms to an automotive axle using the straight-polarity inert-gas metal-arc process



oversensitive control may cause wide variations in arc length as the arc is established.

The constant-potential system usually has a higher first cost, but its inherent stability, simplicity and trouble-free operation more than overcome the additional cost. It is considered to be the best system available today for automation.

Typical Applications

Examples have been selected to illustrate the application of a process for a particular advantage. They also show to some extent how far a process has progressed toward full automation.

Figure 5 shows an automatic machine for welding a truck axle by the submerged-arc process. Two end forgings and the tube are manually loaded into the holding fixture and clamped. As the axle rotates, two welds are completed simultaneously. The submerged-arc process is used on this application to take advantage of its high deposition rate for filling the deep groove between the end forging and tube.

An automatic machine for welding stator-core assemblies by the inert-gas-shielded tungsten-arc welding process is shown in Fig. 6. The machine has a turntable upon which 12 stacking fixtures are mounted equidistant from each other. Loose laminations are loaded into each fixture manually. The turntable then indexes until the loaded fixture reaches a hydraulic ram which presses and sizes the laminations. Four vertical-down welds are made simultaneously across the edges of the laminations while under the pressure of the ram. The operation is completed after the turntable progresses to the ejection station where the assembly is pushed out of the fixture. Approximately 700 stator assemblies can be welded per hour. Since filler metal is not required, the tungsten-arc process is ideally suited for this application.

Fig. 9—A machine for welding lugs to a transformer tank by the straight-polarity inert-gas metal-arc process

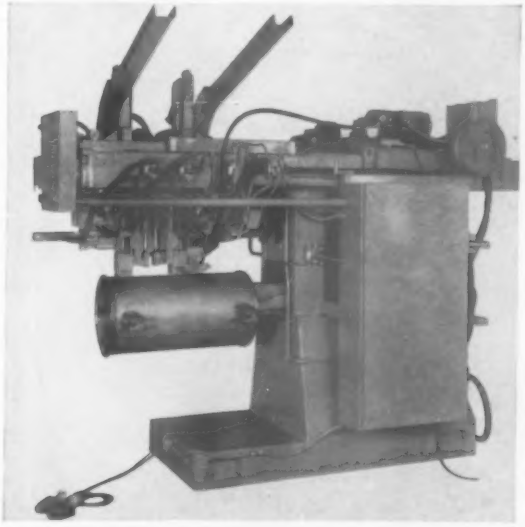


Figure 7 illustrates a machine for welding a small motor frame and core assembly. In addition to the welding operation, a machining and an assembly operation are completed during the cycle.

The machine includes a four-station turntable with a holding fixture at each station. Stator assemblies and rolled frames are manually loaded on the turntable at the station next to the operator's control box. The turntable then indexes clockwise to the welding station. The seam on the frame is longitudinally welded by the inert-gas-shielded consumable-electrode process. Weld penetration is sufficient to join the stator core to the frame. During the welding operation, a hole is drilled in the side opposite the seam. At the third station, a dowel pin is driven into the hole to join the frame and stator core on the opposite side. The completed assembly is ejected at the last station. The consumable-electrode process provides the necessary fill and penetration without the problems associated with a process using flux.

The first large, fully automatic installation of the straight-polarity inert-gas-shielded consumable-electrode process was made in an automotive rear axle plant.[4] Cover-plate-to-housing and housing-to-flange welds have been in production with this process since 1955. Figure 8 shows a fixture for welding three control arms to the axle. Six welds, two on each leg of an arm, are completed in one operation. Two complete clamping fixtures are mounted on opposite sides of a two-station indexing table. With this arrangement, a manual loading operation takes place at the front station while an axle assembly is welded at the rear station. Of particular interest is the configuration of the weld bead. Since the control arms near the ends of the axle are not perpendicular to the axle centerline, the weld must follow a spiral-like seam. To follow the weld, not only must the axle rotate, but the torch must move in a direction parallel to the axle centerline. The selection of the straight-polarity inert-arc process was based on the high welding speed attained and the ability of its wide-bead characteristic to compensate for variations in seam position and fit-up.

Another application of the straight-polarity inert-gas-shielded consumable-electrode process is shown in Fig. 9. In this application, two hanger lugs are welded to the side of a transformer tank. The tanks are loaded on a horn jig provided with clamps to hold the tank in place. Two chutes for feeding the lugs and a carriage for mounting the welding torches are supported by an upper beam. At the start of the cycle, two lugs are lowered into place and clamped automatically. Two torches descend, one on each side of the first lug, to weld the full length of the lug. The torches then move at rapid traverse speed to the second lug. Travel speed is then reduced to welding speed and the second lug is welded.

Fig. 10—A view of an automotive rear axle showing the completely welded assembly and the detail parts

The torches then retract and the clamps release the tank. As shown here, the tanks are manually loaded. However, the machine was installed with automatic loading devices which makes the operation completely automated. As with the previous example, high welding speed and wide bead characteristics were the determining factors in the choice of the straight-polarity process.

Considerable savings have resulted from the proper application of the consumable-electrode CO_2-shielded process. The automotive industries have been instrumental in encouraging its application. The detail parts of a rear-axle assembly are illustrated in Fig. 10. The completely welded assembly is shown in the top view. All of the welds except the banjo seam weld use the CO_2-shielded process with $^3/_{32}$-in. diam electrode wire.

The fixture for welding the cover plate to banjo, shown in Fig. 11 rotates the assembly in a plane 40 deg from horizontal to achieve proper flow of molten metal. Parts are manually loaded and unloaded.

After the cover-plate-to-banjo weld is completed, the assembly is transferred to the fixture shown in

Fig. 11—A view of the cover-plate-to-banjo fixture in operation using the CO_2-shielded metal-arc process

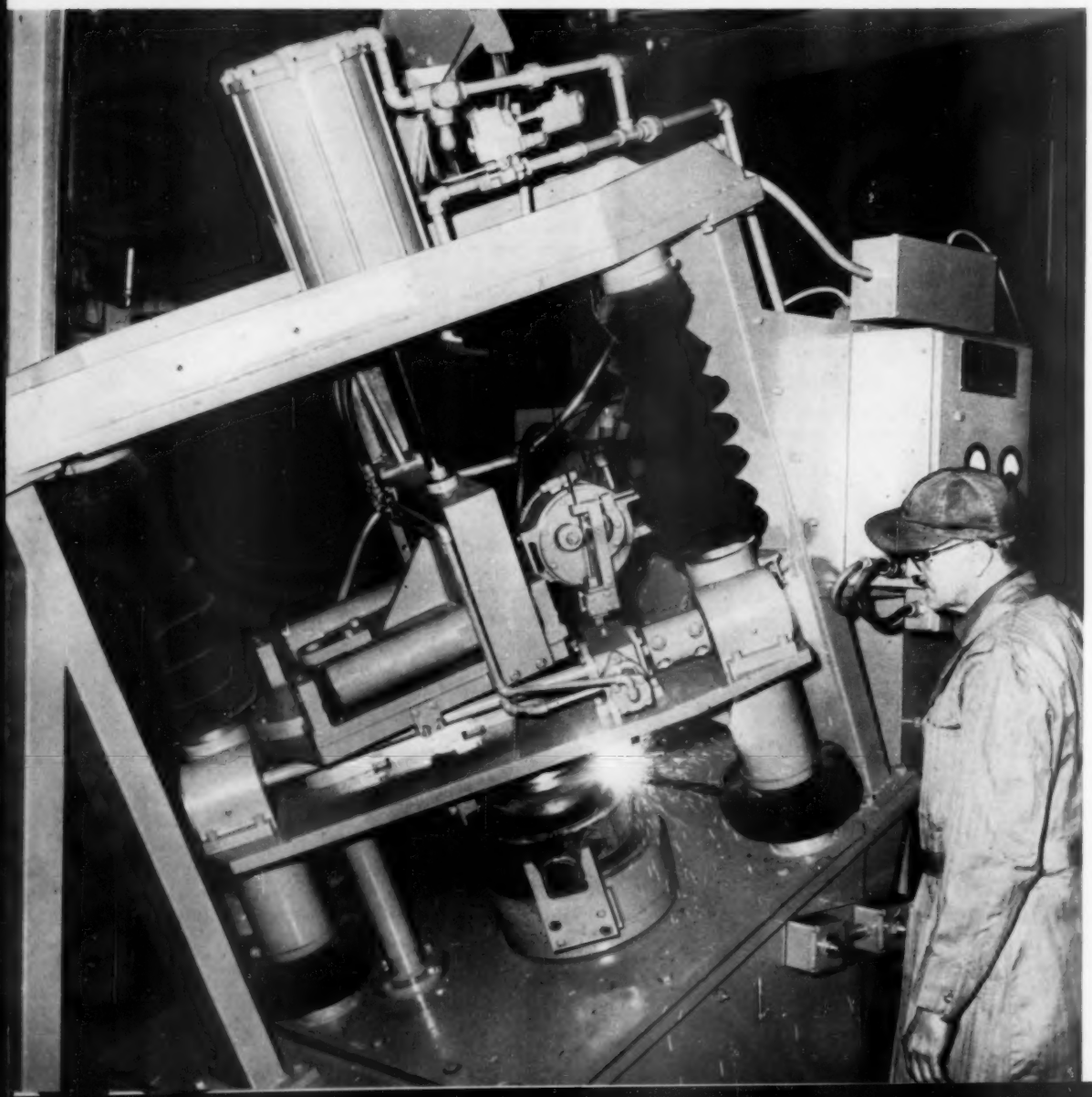


Fig. 12. In this operation, tubes are pressed into the banjo assembly and joined by two simultaneous welds. As with the cover-plate weld, provision is made for proper flow of weld metal by positioning the arc ahead of the top center of rotation. Completed parts are then transferred by conveyor to the next operation.

Figure 13 is a view of the fixture for welding the flanges to the end of the axle. Axles from the previous assembly move into the fixture automatically and the flanges are pressed into the tubes. The joining operation is similar to the tube-to-banjo weld. The completed axle is ejected through the back of the fixture onto a conveyor. The selection of the CO_2-shielded process for this series of welding operation was based on its high welding speed and low cost.

Further reductions in cost have been achieved by the addition of a reactor to the welding circuit. Figure 14 shows a torque tube which originally was welded by the CO_2-shielded process using an 0.040-in. diam electrode. By adding a properly designed reactor to the circuit and readjusting the arc voltage, it was possible to use an 0.091-in. diam electrode with a corresponding savings in cost.

Conclusion

Much progress has been made in the development of arc-welding processes and automatic equipment to answer the need for a high-production tool for joining mild steel and aluminum parts.

Installations such as those used in the automotive industry have highlighted the economies inherent in an automated arc-welding process, particularly those that utilize argon and CO_2 shielding.

Experience so far has indicated that continuing research and development will bring solutions to the metals-joining problems of manufacturers utilizing mild steel and aluminum. Fixturing and actual automation of these new versatile welding processes must be developed to keep pace with the technological growth in the welding industry. Fixturing must be designed around devices which will follow seams and adjust current according to conditions. These devices will lead to welding operations which ultimately will be controlled by computers.

This combination of new challenges from the metalworking industry, the research and development programs of welding manufacturers, and the electromechanical contribution of the fixture builder will bring about the economically sound concept of complete automation of the arc-welding process.

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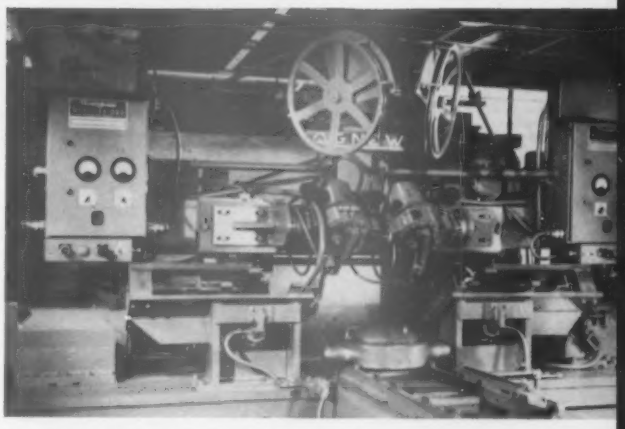
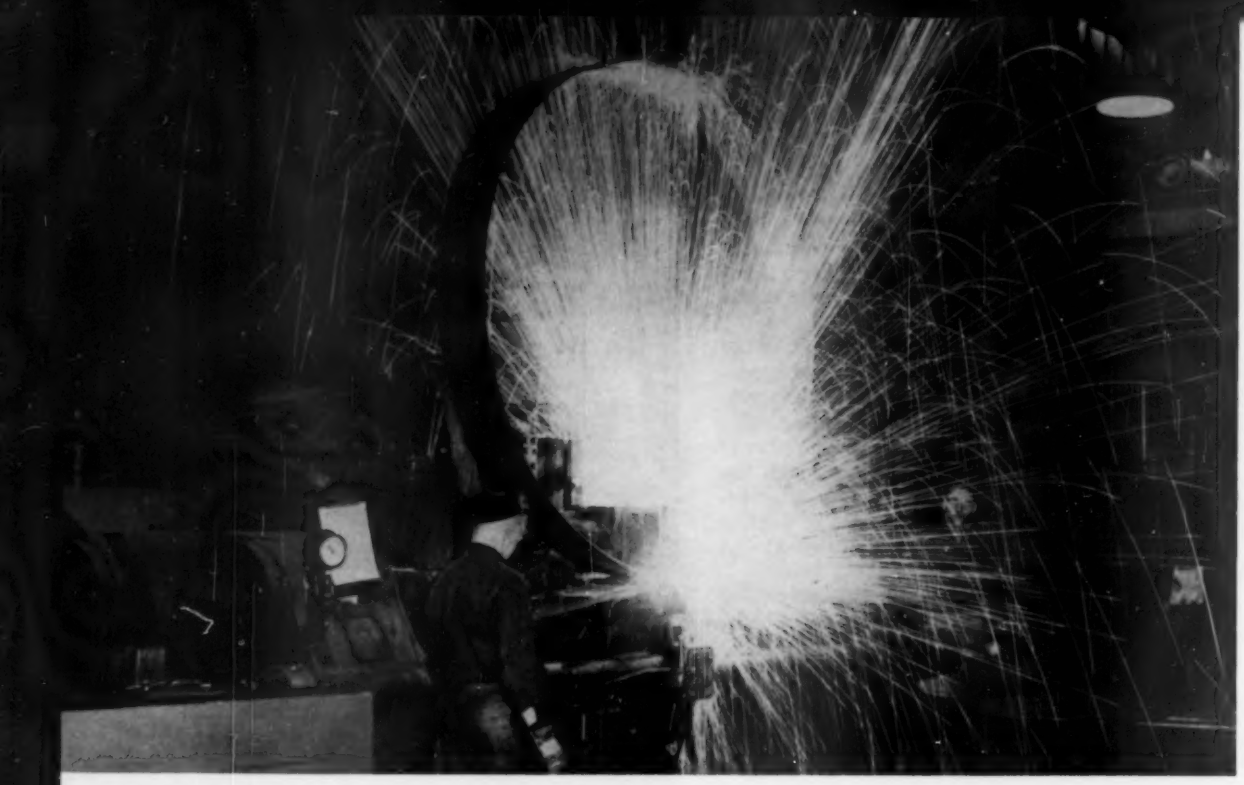


Fig. 12—The tube-to-banjo welding machine showing equipment for the CO_2 process

Fig. 13—The fixture for making the tube-to-banjo weld with the CO_2 process

Fig. 14—A torque tube showing a weld made with a reactor in the welding circuit. Electrode is 0.091 diam at 200 amp



Flash-butt welding of jet-engine rings at a North American Aviation Plant

Article provides a basic understanding of design, general construction, current manufacturing practice, rating and operating characteristics of

Transformers for Resistance-Welding Machines

BY JOSEPH J. RILEY

SUMMARY. The transformer is the heart of the resistance-welding machine. Its theory of design is similar to other transformers, but its details differ sufficiently to puzzle an engineer continually.

This article is written to provide a basic understanding of resistance welding-machine transformer design, general construction, current manufacturing practice, transformer rating and operating characteristics. This knowledge should enable best application and operation of resistance-welding equipment and thereby assist efficient production with these versatile mass-production tools.

Application

In a welding machine, the transformer furnishes a high secondary welding current at low voltage, taking power from the user's primary-supply mains.

The welding current will range from 10,000 to 100,000 amp in normal applications and is intermittent. This loading is expressed as "percent duty cycle."

The power-supply load, expressed in kva (kilovolt-ampere) demand, is in general several times the transformer kva rating.

The transformer secondary is connected into the secondary of the welding circuit of the machine. This is almost a short-circuit condition and the circuit impedance is expressed in microhms (ohms $\times$ 10^{-6}) because of its small value.

The loading is seldom continuous. The intermittent type of loading has a considerable influence on the design of the transformer. If a spot-welding transformer is operating at its full thermal rating at a 2% duty cycle, it is supplying five times its rated secondary current (50% duty-cycle basis), or seven times the permissible continuous secondary current. Transformer rating will be discussed later.

The high current places severe mechanical forces

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and stresses on the primary and secondary coils, tending to move them with respect to each other, and the core. Precautions must be taken in design and manufacture to restrain this movement or it will abrade the insulation badly and cause failure. Good construction will make the primary, secondary and core a rigid mass. Dipping the assembled transformer into insulating varnish and baking it greatly assists in providing a rigid unit.

Construction

The detailed construction of a resistance-welding transformer is basically the same over a range of 30 to 600 kva. This construction will be illustrated here, although it may vary in both the smallest and largest sizes.

Primary Winding

The primary winding consists of a number of disk-type or "pancake" coils. These coils are wound by a winding lathe over a coil form, and restrained between two end plates (see Fig. 1). The wire is unwound from one or more reels. At each coil corner, the lathe is stopped and the strand lightly tapped with a rawhide faced mallet to snug it firmly to the previous turn. The coil has the following characteristics:

1. The wire is flat with rounded edges with the thickness and width controlled to close tolerances. It is not conventional strap copper.

2. The width is normally limited to a maximum of 0.750 in. to reduce the eddy-current losses.

3. The thickness of any strand seldom exceeds 0.105 in. Thus the wire is flexible for a resulting tight coil. If a greater copper cross section is required, multiple strands are wound in parallel.

4. The wire is generally bare. At times, it may have a cotton covering for Class A type insulation transformers. No covering of Class B type insulation is satisfactory for the majority of welding transformers. Therefore, "between-turns" insulation in tape form is used.

5. Fibreglass tape, varnished fibreglass, flexible mica or other combinations of mylar, asbestos and mica are used as "between-turns" insulation.

6. The "between turns" insulation may be any thickness from 0.005 to 0.032 in. as determined by a specific design. Its width is approximately $^{3}/_{32}$ in. wider than the wire. This insulating tape must be centered over the wire so it extends an equal amount on each side of the wire, forming the dielectric barrier around the edges of the wire.

7. Extra insulation (usually mica) is placed inside the first turn or nearest the core, and outside the last turn for added dielectric strength and resistance to mechanical abuse.

The typical coil construction is illustrated in Fig. 2.

After the coil is wound, it is carefully removed from the coil form. The coil is generally taped in local areas prior to its removal, to keep it together and retain its shape. The outside of the coil is covered with tape, lapped $^{1}/_{2}$ of the tape width, so that it is covered with a double thickness of tape. The tape is commonly braided fibreglass. Figure 3 shows a coil being taped.

In some designs, the coil is now dipped in varnish, allowed to drain and then baked. The coil must be suspended carefully to promote an even drainage of the varnish and thus avoid unequal buildup on its outer surfaces.

Fig. 1—Tape is used to insulate successive turns of the primary coil. Taps are brazed as the winding progresses

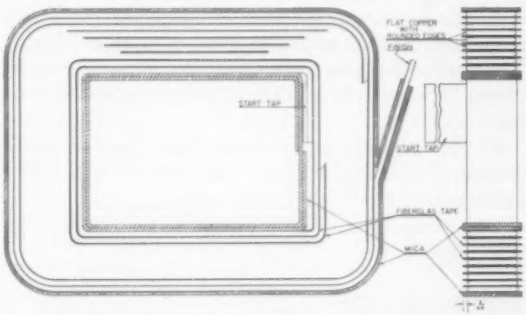


Fig. 2—Disk-type coil prior to application of outer insulating tape

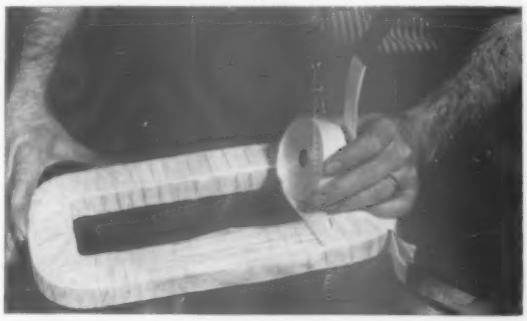


Fig. 3—The outer-tape wrapping is applied

Secondary Winding

The secondary winding is not made from wire but is a rigid member made from a high-conductivity-copper casting or is fabricated from rolled electrolytic-copper bar or plate. Its characteristics are:

1. One or more fins are assembled in parallel, making (usually) one secondary turn. More than one fin is used when the copper cross section must be increased because of the necessary current rating.

2. The fins typically are $^3/_8$ to $^1/_2$ in. wide.

3. Copper tubing is phosphor-copper welded to the outside edges of the fins. This tubing is the water circuit for cooling both the secondary and the primary (indirectly). The welding for the tubing to the secondary is shown in Fig. 4.

In some designs, the secondary fin is a rectangular copper tube. The internal passage may be used for cooling fluid.

4. The fins terminate in flat pads which are part of the secondary if a casting, or are added by brazing or welding if the secondary is fabricated.

5. Ears are attached to each pad. At assembly, these ears are bolted together using insulated bolts. The secondary effectively becomes a mechanically closed loop able to resist high stresses without movement.

6. The surfaces of the secondary fins are made smooth by sanding, grinding, etc., before the secondary is assembled into a transformer.

The construction of a fabricated secondary is illustrated in Fig. 5.

Transformer Core

The core must supply the magnetic flux required without using an excessive exciting or magnetizing current. The RWMA (Resistance Welder Manufacturers' Assn.) Standard limits the no-load current to 10% of the rated current for transformers rated 5 to 100 kva, and to 5% of the rated current for larger units, measured at the maximum secondary voltage.

The useful flux of a transformer is that which passes through the core center leg (not around it) and is linked by both the primary and secondary windings.

Transformers using conventional 4%-silicon transformer iron are normally designed for a maximum flux density between 75,000 and 85,000 lines per square inch. Assume a connection to 60 cps a-c power-supply source. If the factors of 60 cps and flux density are held constant, the core center-leg size or cross-sectional area depends solely on the maximum secondary voltage, not on the kva rating.

The theoretical formula for calculating the cross-sectional area at 60 cps frequency and 0.95 stacking factor is:

$$A = \frac{395{,}000E_s}{BN_s} \qquad (1)$$

where

A = core cross-sectional area, sq in.

Fig. 4—The coolant tube is brazed to all fins of the secondary winding

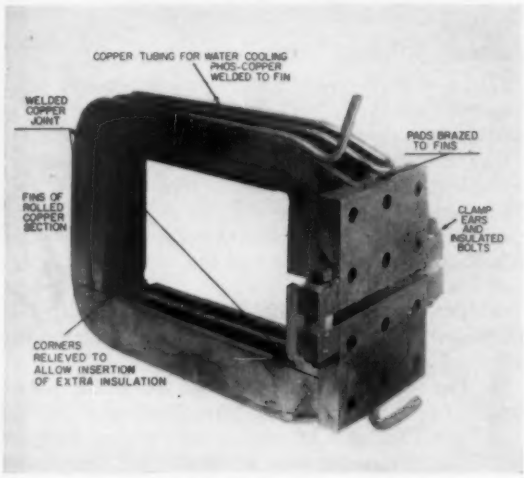

COPPER TUBING FOR WATER COOLING
PHOS-COPPER WELDED TO FIN
WELDED COPPER JOINT
PADS BRAZED TO FINS
FINS OF ROLLED COPPER SECTION
CLAMP EARS AND INSULATED BOLTS
CORNERS RELIEVED TO ALLOW INSERTION OF EXTRA INSULATION

Fig. 5—Secondary of a resistance-welding transformer, fabricated of rolled-copper sections

B = flux density, lines per square inch
E_s = secondary voltage, v.
N_s = number of secondary turns (one in most cases)

Thus, a 125-kva transformer with a maximum secondary voltage of 10 v will have a core leg cross-sectional area practically equivalent to a 300-kva transformer with a maximum secondary voltage of 10 v. The core will be slightly larger in the case of the 300 kva size as the added volume of the additional number of coils and secondary fins increases the length of the return-flux path. However, the size of each of the coils and fins will be similar for the two transformers.

Types of Cores

Two types of cores are used. One is called the "core type," the other the "shell type." These are illustrated in Fig. 6.

In most cases, the cores are made of stacked iron; that is, of sheet transformer steel. Better transformers are made of 4% silicon transformer steel which is "core plated" (a surface finish similar to varnish) to reduce eddy-current losses. The lamination thickness varies from 0.014 in. (29 gage) to

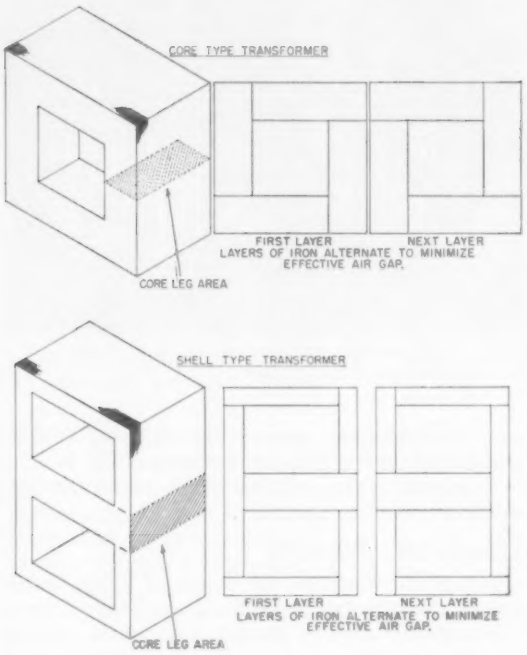


Fig. 6—Types of transformer cores

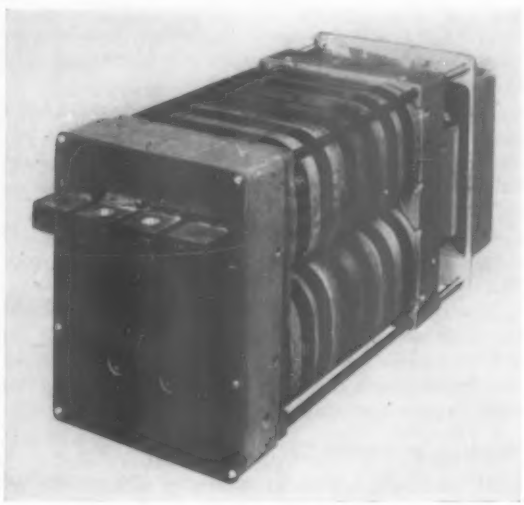


Fig. 7—Transformer made with "grain-oriented" steel core with cover removed

0.025 in. (24 gage). Joints are made as tight as possible to reduce any air gaps. The joints in adjacent laminations are overlapped to further reduce the air gaps. This procedure is illustrated in Fig. 6.

"Core-type" cores are used for smaller transformers, 30 kva and under. These transformers use layer-wound primaries and are normally air cooled.

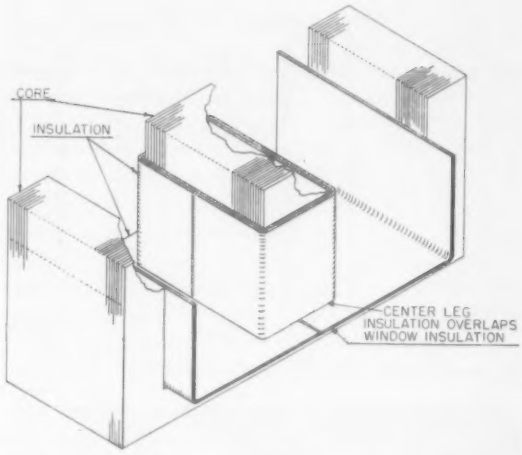


Fig. 8—Placement of core insulation

"Shell-type" cores are used extensively. Using this type of design results in a rigid transformer with the combination of primary, secondary and core being firmly pressed together. "Shell-type" cores have considerably less leakage flux. This minimizes heating of metal parts near the transformer and also decreases its impedance.

Grain-oriented Steel Cores

Transformers having minimum physical size may employ cores made of "grain-oriented" steel commonly referred to as "hypersil." This grain-oriented steel may be operated at a flux density of approximately 120,000 lines per square inch.

Recalling the basic formula (eq 1),

$$A = \frac{395{,}000E_s}{BN_s} \qquad (1)$$

it is obvious that the larger the value of B (flux density), the smaller A (core area) can be. Reducing A enables reduction of the value of "mean turn length" of the primary coils and secondary fins and results in smaller size and less copper in a transformer of a given rating.

The grain-oriented steel cores are normally built as two U-sections which are assembled around the primary and secondary. The two parts of each core are held together by banding. The contacting faces are matched to produce a small effective air gap.

An example of a transformer using grain-oriented steel cores is shown in Fig 7.

Insulating the Core

The core cannot be completely assembled before the secondary and primary windings are installed.

The core for the shell-type transformer is partially assembled until it takes the form of a letter E. When it has reached this stage, it is ready to be insulated.

The core is insulated by placing plate mica or

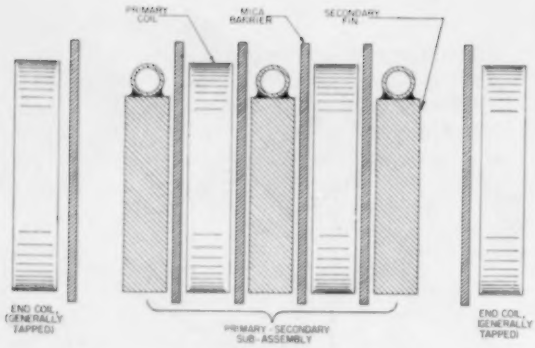


Fig. 9—Arrangement of the winding assembly

Fig. 10—Blocking the windings of the transformer for a tight assembly

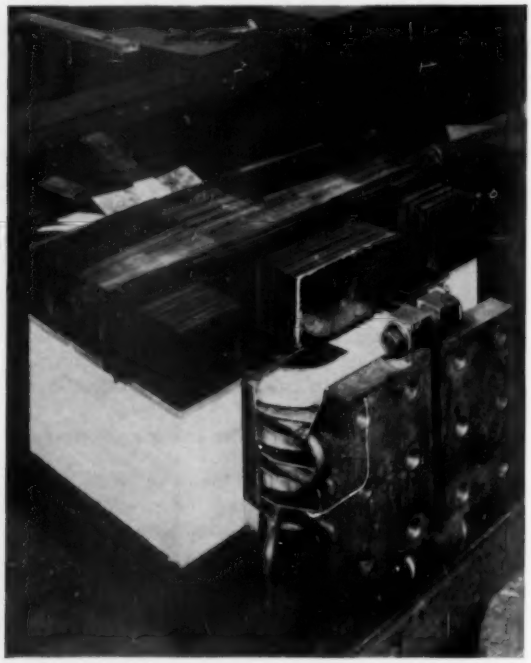


Fig. 11—End iron being applied to complete the core

Fig. 12—Transformer-core clamps tighten the stacked-iron core and serve as mounting feet

equivalent material around the core leg. Other pieces are placed in the core as shown in Fig. 8.

At this stage, the core is ready to take the primary-secondary winding assembly.

Transformer Assembly

Before the windings can be placed in the transformer, it is necessary that all the primary coils, except the two end coils (the first and last), be inserted in the secondary winding. On each side of each coil, the barrier insulation, generally plate mica or equivalent, is inserted.

The general arrangement is shown in Fig. 9.

The first end coil is placed in the transformer core, then the primary-secondary subassembly, and finally the last end coil.

When the primary-secondary subassembly is in place, it is equally spaced around the core center leg. It is held away from this center leg by strips of insulation called blocking. This operation is shown in Fig. 10.

After the transformer is blocked, the magnetic circuit of the core is closed by inserting the end iron, Fig. 11.

The transformer components are tightly pressed together and the core clamp added. It may be welded or held by bolts. The core clamp serves as the frame which contains the mounting feet. The addition of a core clamp is indicated in Fig. 12.

Varnish-and-bake Cycle

Much of the insulation resistance of a resistance-welding transformer is added in the insulating-varnish cycle. Much of the transformer's ability to withstand severe mechanical stresses is also added during the varnish cycle. Heat conductivity (from primary to secondary) is improved.

The purpose of the varnish is to exclude as much air as possible and fill any voids with varnish. While dry air is a good insulator, damp air is not. The very close spacing of the primary and secondary makes the air-column length very small. This factor, combined with the difference in dielectric constants of the various insulations used, may severely stress the small air columns in damp weather, and

Fig. 13—The primary leads of the welding transformer are attached by brazing

cause corona and an insulation breakdown.

It is imperative that a satisfactory varnish be selected which has the characteristic of very good penetration and yet have sufficient body to fill up the small voids that exist throughout the unit. The temperature rating of the varnish is usually adequate for Class B insulation.

The varnishing-and-baking cycle takes considerable time. The transformer is placed into an oven to preheat it. This initial heating serves to drive off most of the moisture that has accumulated in the assembly during manufacture.

After preheating, the transformer is dipped into the varnish tank until it is thoroughly filled with varnish. The unit is then allowed to drain. After the excess varnish has drained, the unit is placed in the baking oven to cure the varnish. The transformer is then removed and allowed to cool for a controlled time. When the transformer has cooled it is again dipped and baked.

Accumulated varnish on the secondary terminal surfaces and the primary coil terminals is then removed.

Adding the Primary Connections

The transformer is completed by brazing the primary lead cables to the coil taps. This seemingly simple operation requires skill in order to avoid damage to the transformer insulation by the heat of the brazing operation.

While the brazing operation is being performed, the remainder of the coil must be kept cold. This can be accomplished by packing the coil in damp asbestos prior to the brazing operation.

The unit can be sufficiently cooled by directing an airstream over the heated area as the brazing is progressing, as indicated in Fig. 13.

The transformer is now ready for installation in the resistance-welding machine.

Electrical Characteristics

Various existing standards, ASA,* AIEE† and RWMA‡ cover the performance of the transformer.

* American Standards Assn.
† American Institute of Electrical Engineers.
‡ Resistance Welder Manufacturers' Assn.

The performance and characteristics of a transformer cannot be expressed readily without equations. However, since we wish to familarize the user with the pecularities of a resistance-welding transformer (rather than emphasize the elements of design), mathematics here will be limited. Simplifying assumptions will be applied to establish the basic concepts.

Kilovolt-Ampere (Kva) Rating

The kva rating of a resistance-welding transformer seems to be as mystifying a topic as any which exist in the welding industry. There are three factors which confuse the issue:

(*a*) The transformers are rated at 50% duty cycle (based on a 1 min. integrating period); not the 100% duty cycle which applies to most transformers.

(*b*) The transformers are rated on a specific input, not on output as are most transformers.

(*c*) Tapping the primary winding gives a large range of secondary voltage but results in different permissible kva loads, dependent on the tap used.

The kva rating is a thermal rating. If a transformer carries a 50% duty-cycle load to the limit of its kva rating (input), the temperature rise of the windings should not exceed a figure normally considered satisfactory for the type of insulation used in the transformer.

The kva rating is no indication of what secondary current will exist in the secondary circuit of a welding machine. The secondary current is a function of the impedance (machine and transformer) and the transformer secondary voltage, not the kva rating.

Duty Cycle

The concept of "duty cycle" must be understood before kva rating is clear. Duty cycle is the percent of time that the load is applied during the integrating period.

The integrating period is the sum of a load and a rest period when the transformer is operated for alternate periods of kva input and rest, in which the kva input conditions are recurrent as to magnitude and duration.

The integrating period by RWMA standards is 60 sec (or 3600 cycles at 60 cps frequency).

At 50% duty cycle the load period is equal to the rest period, or 30 seconds each, for a 60-sec integrating time.

Resistance-welding machines seldom operate at 50% duty cycle. They have an equivalent kva loading at other duty cycles. The duty cycle is conveniently calculated from the equation

$$d = \frac{tN}{36} \qquad (2)$$

where

d = duty cycle, %
t = load (or current flow) time in cycles (60 cps)
N = number of loads (spots) per minute

As an example, find the duty cycle of a spot-welding machine making 120 spots per minute using a 5-cycle weld time

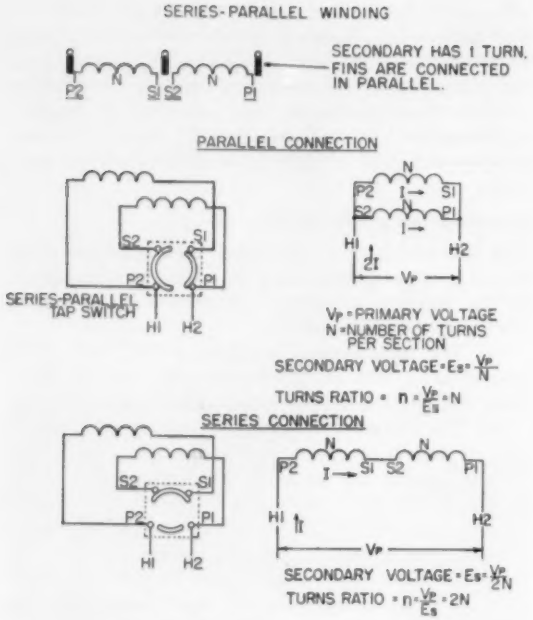

SERIES-PARALLEL WINDING
SECONDARY HAS 1 TURN. FINS ARE CONNECTED IN PARALLEL.
P2 N S1 S2 N P1
PARALLEL CONNECTION
SERIES-PARALLEL TAP SWITCH
HI H2
Vp = PRIMARY VOLTAGE
N = NUMBER OF TURNS PER SECTION
SECONDARY VOLTAGE = Es = Vp/N
TURNS RATIO = n = Vp/Es = N
SERIES CONNECTION
SECONDARY VOLTAGE = Es = Vp/2N
TURNS RATIO = n = Vp/Es = 2N

Fig. 14—Series-parallel winding and connection diagrams

$$t = 5 \text{ cycles}, N = 120$$

$$d = \frac{5 \times 120}{36} = 16.7\%$$

Permissible Kva Loading at Various Duty Cycles

As normally applied, resistance-welding equipment will operate at less than 50% duty cycle. It is thus necessary to express the permissible kva loading at different duty cycles.

Permissible kva at a given duty cycle may be determined by:

$$\text{kva}_D = \text{kva}_R\sqrt{\frac{50}{d}} \qquad (3)$$

Table 1—Value of f_1 for Different Duty Cycles in Eq 4, $\text{kva}_D = f_1\ (\text{kva}_R)$

Duty cycle, %	Factor f_1
1	7.08
2	5.00
3	4.07
4	3.53
5	3.15
7.5	2.57
10	2.23
15	1.82
20	1.58
25	1.41
30	1.29
35	1.195
40	1.115
50	1.00
60	0.912
70	0.843
80	0.787
90	0.745
100	0.707

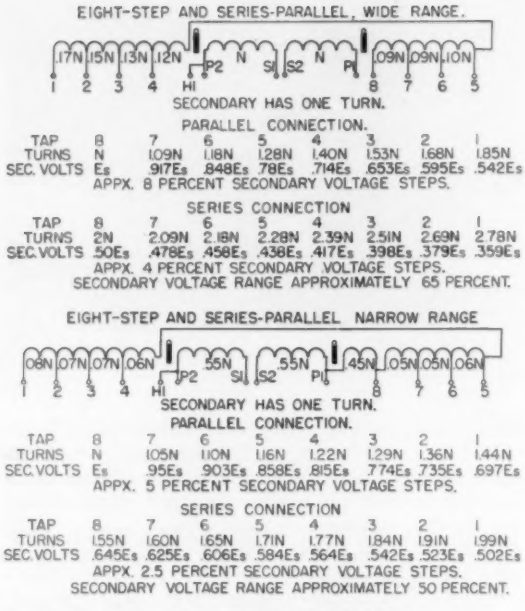

EIGHT-STEP AND SERIES-PARALLEL, WIDE RANGE.
.17N .15N .13N .12N N .09N .09N .10N
1 2 3 4 HI P2 S1 S2 P1 8 7 6 5
SECONDARY HAS ONE TURN.
PARALLEL CONNECTION.
TAP 8 7 6 5 4 3 2 1
TURNS N 1.09N 1.18N 1.28N 1.40N 1.53N 1.68N 1.85N
SEC. VOLTS Es .917Es .848Es .78Es .714Es .653Es .595Es .542Es
APPX. 8 PERCENT SECONDARY VOLTAGE STEPS.
SERIES CONNECTION
TAP 8 7 6 5 4 3 2 1
TURNS 2N 2.09N 2.18N 2.28N 2.39N 2.51N 2.69N 2.78N
SEC. VOLTS .50Es .478Es .458Es .438Es .417Es .398Es .379Es .359Es
APPX. 4 PERCENT SECONDARY VOLTAGE STEPS.
SECONDARY VOLTAGE RANGE APPROXIMATELY 65 PERCENT.
EIGHT-STEP AND SERIES-PARALLEL NARROW RANGE
.08N .07N .07N .06N .55N .55N .45N .05N .05N .06N
1 2 3 4 HI P2 S1 S2 P1 8 7 6 5
SECONDARY HAS ONE TURN.
PARALLEL CONNECTION.
TAP 8 7 6 5 4 3 2 1
TURNS N 1.05N 1.10N 1.16N 1.22N 1.29N 1.36N 1.44N
SEC. VOLTS Es .95Es .903Es .858Es .815Es .774Es .735Es .697Es
APPX. 5 PERCENT SECONDARY VOLTAGE STEPS.
SERIES CONNECTION
TAP 8 7 6 5 4 3 2 1
TURNS 1.55N 1.60N 1.65N 1.71N 1.77N 1.84N 1.91N 1.99N
SEC. VOLTS .645Es .625Es .606Es .584Es .564Es .542Es .523Es .502Es
APPX. 2.5 PERCENT SECONDARY VOLTAGE STEPS.
SECONDARY VOLTAGE RANGE APPROXIMATELY 50 PERCENT.

Fig. 15—Eight steps and series-parallel winding

where

d = duty cycle, %
kva_R = kva rating at 50% duty cycle
kva_D = permissible kva loading at required duty cycle.

From this equation, a factor, $f_1 = \sqrt{50/d}$, can be determined which gives the permissible kva loading in terms of standard rating at 50% duty cycle.

The value of f_1 for different duty cycles is tabulated in Table 1.

This factor is used in eq 4.

$$\text{kva}_D = f_1\ (\text{kva}_R) \qquad (4)$$

From this equation and Table 1, the permissible kva loading of a 50 kva transformer at 3% duty cycle is 50 (4.07) = 203 kva.

Types of Primary Windings

Practically all resistance-welding transformers have a secondary-voltage range resulting from the tapping of the primary winding. There are two principal arrangements of windings presently furnished: series-parallel, and eight-step and series-parallel. The latter furnishes 16 secondary voltage values.

Because of the tapping, transformers are generally designed to operate from *one primary voltage only*. Dual primary-voltage transformers are more complex and costly.

Series-parallel Winding

The simplest form of winding is the series-parallel type. The winding contains two sections which can be connected in series or parallel. The schematic representation is shown in Fig. 14, for both the parallel and series connections. This winding provides

two values of secondary voltage.

If each section of the winding of N turns can carry a current I at 50% duty cycle without overheating, it is obvious that in the parallel connection the line current can be $2I$. In the series connection the line current can be I.

The secondary current is the same value for both connections and is equal to the rated secondary current.

Eight-step and Series-parallel Winding

This form of winding, operating from one primary voltage, provides eight different secondary voltages in either the parallel or series connection. The use of eight steps is common throughout the industry and is covered in RWMA standards.

The maximum secondary-voltage range that can be covered with this arrangement is from E, to 0.36 E, provided all steps give different secondary voltages; that is, no overlapping. This winding is shown in Fig. 15, "wide range."

If this secondary-voltage range is covered, there will result an 8% increment between steps in the parallel connection and a 4% increment in the series connection.

The secondary-voltage increment between taps can be decreased at the expense of decreasing the over-all range between maximum and minimum secondary voltages (see Fig. 15, "narrow range"). There is a 5% increment between taps on the parallel connection and a 2.5% increment in the series connection.

The kva rating at any tap is reduced proportional to the secondary-voltage reduction. Rated secondary current is a limitation on any tap.

Kva Limitations at Various Primary Taps and Duty Cycles

In the preceding sections, types of kva loading were discussed. One is the *permissible kva loading* at other than 50% duty cycle. This results from a mathematical analysis of intermittent heating and has no direct connection with the design of the transformer. Another is the *basic kva rating at 50% duty cycle*. As the RWMA standards specify rated secondary current must be delivered at any tap without overheating, this *secondary-current rating* has a direct connection with the design of a transformer.

In any problem concerning the application of a welding transformer in a welding machine, it is necessary to consider both of the above limiting factors.

The actual procedure will be illustrated by considering a typical problem: determine the maximum number of operations per minute that two pieces of 16-gage low-carbon steel can be spot welded on a welding machine. The weld time is 15 cycles, the tap setting is No. 5, parallel. The primary current when welding is 110 amp from a 440-v power supply (60 cps). From the nameplate of the machine its kva rating is 50. The transformer maximum secondary voltage is 5.0 volts. The transformer has an 8-step and series-parallel winding as illustrated in Fig. 15, "wide range."

Step I: Determination of Kva Rating at 50% Duty Cycle at Tap 5. The kva rating will be proportional to the ratio of secondary voltage at the tap used to the maximum secondary voltage. The secondary voltages and ratings at the respective taps are as follows:

Tap	8	7	6	5
Secondary volts	5	4.58	4.23	3.90
Kva rating	50	46	42	39
Tap	4	3	2	1
Secondary volts	3.57	3.26	2.98	2.71
Kva rating	36	33	30	27

Thus at Tap 5 the kva rating equals 39 kva. This is the 50% duty-cycle rating.

Step II: Determination of Maximum Permissible Duty Cycle. The kva demand is the product of the line current, I, and the line voltage, V_p, divided by 1000 or, in equation form:

$$kva_D = \frac{V_p I}{1000} = \frac{440 \times 110}{1000} = 48.5 \text{ kva}$$

The permissible kva demand divided by the kva rating at 50% duty cycle is the factor f_1 in Table 1

$$f_1 = \frac{\text{kva}_D}{\text{kva}_{R*}} \qquad (5)$$

kva_D = permissible kva loading
kva_R = kva rating at 50% duty cycle
f_1 = 48.5/39.0 = 1.24

From Table 1, the permissible duty cycle is 37%.

Step III: Determination of Spots Per Minute from the Permissible Duty Cycle. From eq 2, $d = tN/36$; then, if d = 37% and t (weld time) = 15 cycles, $37 = 15N/36$ and N = 89 operations per minute.

Transformer Impedance

Impedance in a transformer is similar to an internal obstruction to the flow of power. It is made up of leakage reactance and effective resistance. The size of these blocking agents depends on the physical arrangement of the primary and secondary windings, the number of their turns and the copper cross sections used.

The obstruction is conventionally expressed as "percent impedance." If rated load is taken from the transformer, terminal secondary voltage is lower than the open-circuit voltage. This voltage reduction, expressed in percent, is called "percent impedance."

It may also be expressed as that percent of the primary voltage required to furnish rated secondary current when the secondary terminals are short circuited.

For example, consider a 50-kva transformer (rated

* This is the kva rating at the tap used, not the nameplate rating of the welding transformer.

at 50% duty cycle) with a maximum secondary voltage of 8.46 v and 5% impedance as indicated on its nameplate. What will be the maximum secondary terminal voltage* under a load of 16,000 amp?

$$\text{Rated Secondary Current } I_s = \frac{\text{kva}_R(1000)}{E_s}$$

$$I_s = \frac{50 \times 1000}{8.46} = 5900 \text{ amp}$$

For each 5900 amp increment supplied, there is a 5% voltage drop internally in the transformer. Thus at 16,000 amp the percent drop

$$\frac{16{,}000}{5900} \times 5 = 13.6\%$$

The apparent loss in secondary voltage is 13.6%, or $0.136 \times 8.46 = 1.15$ v. The actual secondary voltage at the terminals is $8.46 - 1.15 = 7.31$ v.

Suppose the above transformer of 50-kva rating had a rated secondary voltage of 12.5 v (instead of 8.46 v) and still had 5% impedance.

By following the same procedure, the secondary-voltage drop, due to impedance, is 2.44 v (actually 20%), compared to 13.6% in the previous case. The actual terminal voltage is $12.5 - 2.44$ or 10.06 v.

These examples point out that, for a kva rating, it is best to use the lowest value of rated secondary voltage that can do the job. Otherwise, additional kva demand will be required for the increased voltage drop.

The impedance of a transformer will change with operation on different taps. An example of a 50-kva welding transformer having an eight-step and series-parallel winding (as typified by Fig. 15, "narrow range") is shown in Fig. 16. The degree of change is typical of transformers of this secondary-voltage range and of 50 to 150 kva rating.

* The ratio of leakage reactance and effective resistance of the transformer as well as the phase angle of the load current is neglected for simplicity.

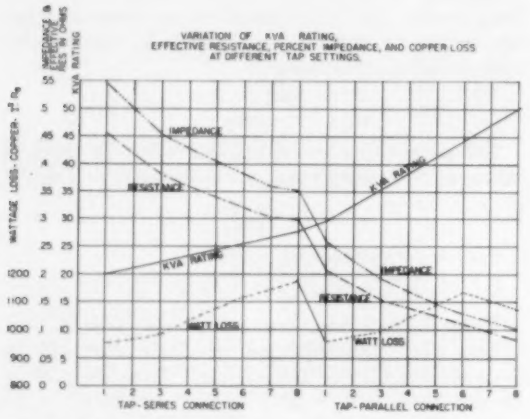


Fig. 16—Characteristics of a 50-kva transformer with an 8-step and series-parallel winding

Watts Loss (I^2R_e Loss)

The heat generated in the transformer is composed of the iron loss (core and hysteresis) and the copper loss. Except for very small transformers, the copper loss will normally be 5 to 10 times the iron loss. The copper loss is equal to the square of the rated primary current multiplied by the effective resistance.

The effective resistance is determined experimentally by shorting the secondary terminals and causing rated secondary current to flow. The power input P (watts) is then measured, as well as the primary current I_p.

The effective resistance, $R_e = P/I_p^2$.

The effective resistance is a definite indication of what loss must be dissipated to the cooling water of the secondary, and to the atmosphere surrounding the transformer.

The effective resistance increases rapidly with the

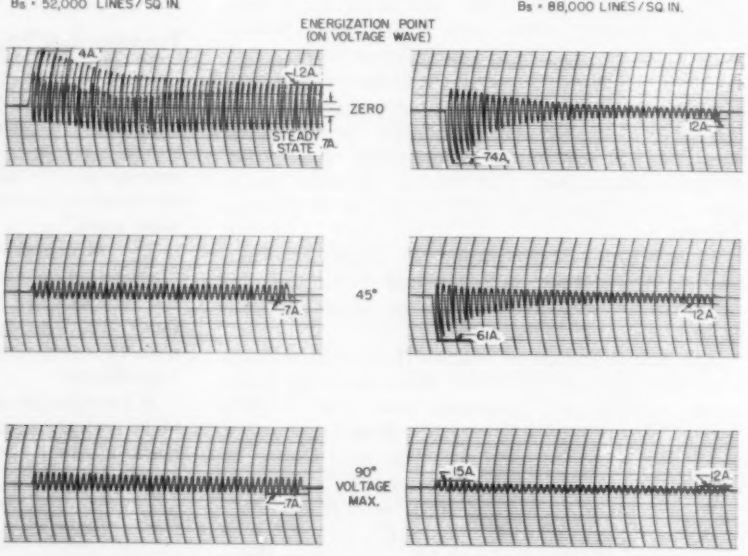


Fig. 17—Changes in initial value of exciting current with energization point on the primary-voltage wave. 50-kva "stacked-iron" transformer

addition of turns (switching to lower taps). *This is the principal reason for decreasing the kva rating of the transformer at the lowest taps.* This is true even if the primary winding is not decreased in cross section at the lower taps. An actual example of a 50-kva transformer (see Fig. 16) shows a typical degree of change.

If the transformer is operated at nameplate kva rating on Tap 1 (instead of Tap 8), the watt loss dissipation will be 2.6 times—260% greater than at Tap 8.

By following the RWMA standards the watt loss at Tap 8 is $0.082 \times 114 \times 114 = 1062$ w. At Tap 1 the loss is $0.215 \times 67 \times 67 = 970$ w. These losses are nearly equal. The copper loss at each tap (in accordance with the kva rating at that tap) is plotted in Fig. 16. This loss remains nearly constant at any tap.

A transformer is more efficient in the parallel connection. If unusual service conditions require overloading for a short period of time, it is definitely desirable to use the "parallel" connection. This will result in the least amount of extra heating (and temperature rise).

Transformer-type Service

In the resistance-welding industry it is quite common to speak of transformer types according to their service, for instance, spot- or press-welding-machine type, seam-welding-machine type, flash-welding-machine type and portable type.

A transformer is a spot-welding-machine type or a seam-welding-machine type as determined by the operating duty cycle. In a spot-welding machine, the usual operating duty cycle ranges from 3 to 5%. In a seam-welding machine, the operating duty cycle ranges from 20 to 65%. The typical figure is 35%.

The effect of duty cycle on design generally results in a seam-welding transformer having a kva rating approximately three times greater than a spot-welding transformer if both have the same secondary voltage.

The flash-welding transformer in sizes under 250 kva is similar to the spot-welding transformer. It is usually protected by a "potting compound" on its secondary terminal end. The addition of the potting compound makes it difficult for the abrasive particles (resulting from the flash-welding operation) to enter between the transformer windings. Tap switches are often mounted in a housing on the transformer primary end. This procedure makes a very well-shielded unit. The portable welding-gun transformer has one unusual characteristic. Its secondary consists of two turns (as discussed under Secondary Windings) which terminate in lugs rather than flat pads. The lugs simplify the necessary cable connections. It is built with a self-contained tap switch and often has provisions for mounting an air-hydraulic booster, air valve and water manifold.

Exciting Current and (Magnetizing) Transients

In service, the resistance-welding transformer is energized and deenergized much more frequently than any other transformer type of equivalent kva rating. The rate of excitation may reach 400 spots per minute. This cycle of constant energization and deenergization produces problems not common to normal transformer service.

The process of establishing the flux in a transformer can cause transient values of exciting current which are many times greater than the "steady-state" value. A detailed analysis of magnetization curves is beyond the scope of this article. To simplify, however, the exciting current transient will chiefly depend on three factors: the value of flux density, the point on the voltage wave at which the transformer is energized, and the type of iron employed.

The practical effects of the first two items in a transformer made of 4% silicon iron is indicated in Fig. 17. This set of curves illustrates changes in "inrush" exciting current under various conditions.

At Tap P-1 (which is the setting for lowest flux density) the inrush exciting current is appreciably lower than at Tap P-8 (highest flux density) at the same energization point on the voltage wave. Note that the current at the most adverse energization point in the P-1 connection is less than the steady state value on P-8.

The behavior of the exciting current in most transformers of the stacked-iron type will follow this pattern.

In a practical sense, the exciting-current transient is not serious enough to warrant any special treatment if a stacked-iron core is operating at approximately 80,000 lines per square inch flux density at its maximum secondary voltage working from a 60 cps source.

The use of grain-oriented iron in a welding transformer introduces a problem because of its characteristic of maintaining a very high flux density at comparatively low steady-state exciting currents. The transient value of the magnetizing current cannot be neglected, especially at high rates of energization, without danger of overheating and producing excessive mechanical forces, both in the welding transformer and the primary supply lines.

The exciting current of grain-oriented iron transformer is shown in Fig. 18. Its pattern is somewhat like the stacked-iron transformer but the magnitudes are very much greater. The initial half cycle approaches 700% of the rated current. There is no reasonable reduction until the firing point approaches 90 deg (line voltage maximum). Delaying the energization point past 90 deg causes the second half cycle of exciting current to be larger than the first.

Within the past few years, electronic welding controls have occasionally been equipped with features to give "90-deg firing." These features have various names such as "transient suppressor," "delayed firing," etc. It is obvious that such controls, with their added complications, definitely are of value when used with grain-oriented, iron transformers. This extra feature is of less benefit when used with stacked-iron transformers.

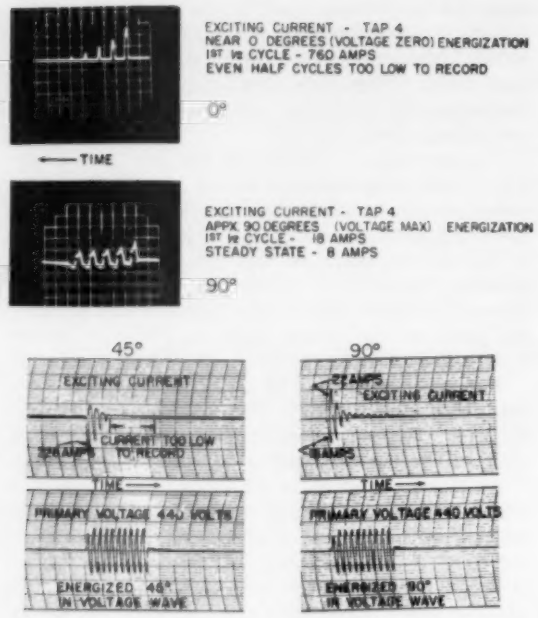


Fig. 18—Changes in initial value of exciting current with energization point on the primary-voltage wave. 50-kva "grain-oriented" iron-core transformer

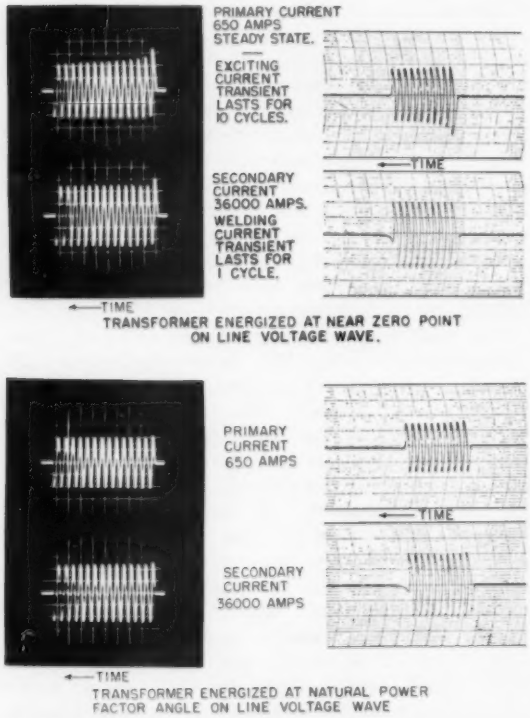


Fig. 19—Exciting-current and load-current transients. 50-kva "stacked-iron" transformer

Load-circuit Current Transients

The load-circuit current can have a transient which is completely separate from the exciting-current transient. An exciting-current transient in the primary winding has only a minor effect on the secondary current. The secondary current will be decreased by the additional voltage drop which is caused by the exciting-current transient. Hence, good welding can take place with severe exciting-current transients. The degree of transient can be controlled partially in transformer design by the proper selection of the type of core iron and the operating flux density. The critical variable, energization point, is beyond the transformer designer's control.

The load-circuit current transient is practically independent of transformer design. It depends on the inductance and resistance of the welding-machine secondary circuit, which are a result of throat geometry and of materials used. However, in the worst case, this transient cannot exceed 200% of the steady-state load current.

Unlike the exciting-current transient (which will last for a number of cycles), the load-circuit transient has a direct effect on the magnitude of the secondary current, but it lasts for only a cycle or two.

The time constant T of the load-circuit current transient for a 60 cps source is

$$T = \frac{1}{377}\sqrt{\frac{1}{PF^2} - 1}$$

where PF = power factor as a decimal.

For a power factor of 0.25, common in long-throat spot-welding machines, T = 0.0102 sec. The transient is generally considered ended at three times the time constant, or 0.0306 sec, which is less than 2 cycles. If the power factor is 0.50, the time of transient ($3T$) is 0.014 sec or less than 1 cycle.

The load-circuit transient is virtually eliminated by firing at the natural power-factor angle of the load (not at the 90-deg firing point). However, if the firing point is delayed to 90 deg, the load-circuit transient will subtract from the steady-state value, resulting in a lower initial secondary-current value.

Simultaneous records of primary and secondary current taken on a 50-kva spot-welding machine with a stacked-iron transformer are shown in Fig. 19.

The conditions are shown when firing near the zero point of the voltage wave (maximum exciting and load-circuit currents) and energization at the natural power-factor angle (no load-circuit transient). The maximum transient condition indicates that the load-circuit transient, visible in the secondary, lasts about one cycle. The magnetizing transient, visible in the primary, lasts about 10 cycles.

At minimum transient, there is practically no load circuit or magnetizing transient. However, had an oriented-grain-iron transformer been used, there would have been a magnetizing transient as the natural power-factor angle was approximately 55 deg. Thus, firing was approximately 30 deg too early to enable elimination of the magnetizing transient.

Practical Welder and Designer

Turntable Slashes Production Time

A new twist in oxygen-cutting procedures has made it possible for Midvale Heppenstall Co., Philadelphia, Pa., to make a big cut in production costs. In standard oxygen-cutting operations, cutting torches are moved over a stationary workpiece. But in the ingenious setup at Midvale Heppenstall the work is positioned on a controlled speed turntable and rotated past stationary cutting torches. On one job, huge multiple-ring forgings were oxygen cut into equal-sized rings in less than one-tenth the time required for machining (Fig. 1).

Five cutting torches mounted on a vertical rig slice the big forgings horizontally as they rotate past the torches. One man regulates the speed of the electrically powered turntable and controls the intensity of the cutting flames. Machining time is drastically reduced. One job on forged rings which formerly took 320 hr is now machined in less than 115 hr using the new method.

Any type of steel, from low-carbon to high-alloy, can be cut with this setup which handles work from 36 in. OD to more than 200 in. Turntable speed can be accurately controlled from 0 to 20 turns per hour. Parts up to 120,000 lb can be carried on the turntable. Torch carriers move on tracks that are radial to the table.

Torches mounted on a horizontal arm are also used to make bevels and vertical cuts. Vertical cuts and deep 40-deg chamfer-cuts on the inside of the rings are made simultaneously (Fig 2). Less than one inch is left on the cut faces for machining. Oxygen-cutting has reduced the total machining time on this operation by more than sixty per cent and frees costly machining equipment for use on closer work (Fig 3).

Based on a story by the Linde Company, New York, N. Y.

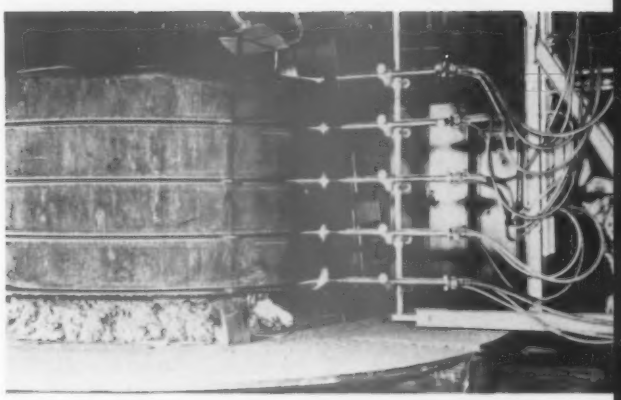


Fig. 1—Five stationary cutting torches make quick, accurate cuts in a multiple-ring forging. This operation produces four rings of equal thickness

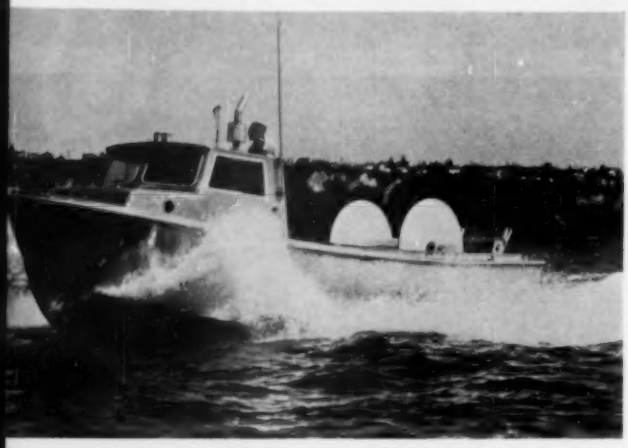
Fig. 2—After a multiple-ring forging is cut into four rings, vertical and angled torches make finishing cuts. A vertical cut on the outside diameter and a 40-deg chamfer cut on the inside diameter are made at the same time

Fig. 3—Top, bottom and center of forged rings are cut simultaneously saving 66²/₃% machining time. One operator regulates turntable speed and the flame intensity of the cutting torches

Welded Aluminum Boats for Salmon Fishing

Ten aluminum gillnetters, new among American fishing boats, are enroute to the Alaska salmon fisheries, after Puget Sound tests which drew enthusiastic comments from commercial fishermen.

Based on a story by Kaiser Aluminum & Chemical Sales, Inc., Oakland, Calif.



A speed of 15 knots was attained by 32-ft aluminum gill-netters, built for the Alaska salmon fisheries, in preliminary trials in the Puget Sound near Seattle

The boats were built by Marine Construction & Design Co., Seattle, for Harold Daubenspeck of Kenai Packers.

Marco (Marine Construction & Design) reported that the aluminum gillnetters, powered by 165-hp gasoline engines, had a speed of 15 knots in preliminary tests, compared with eight or nine knots for most gillnetters (see Fig. 1).

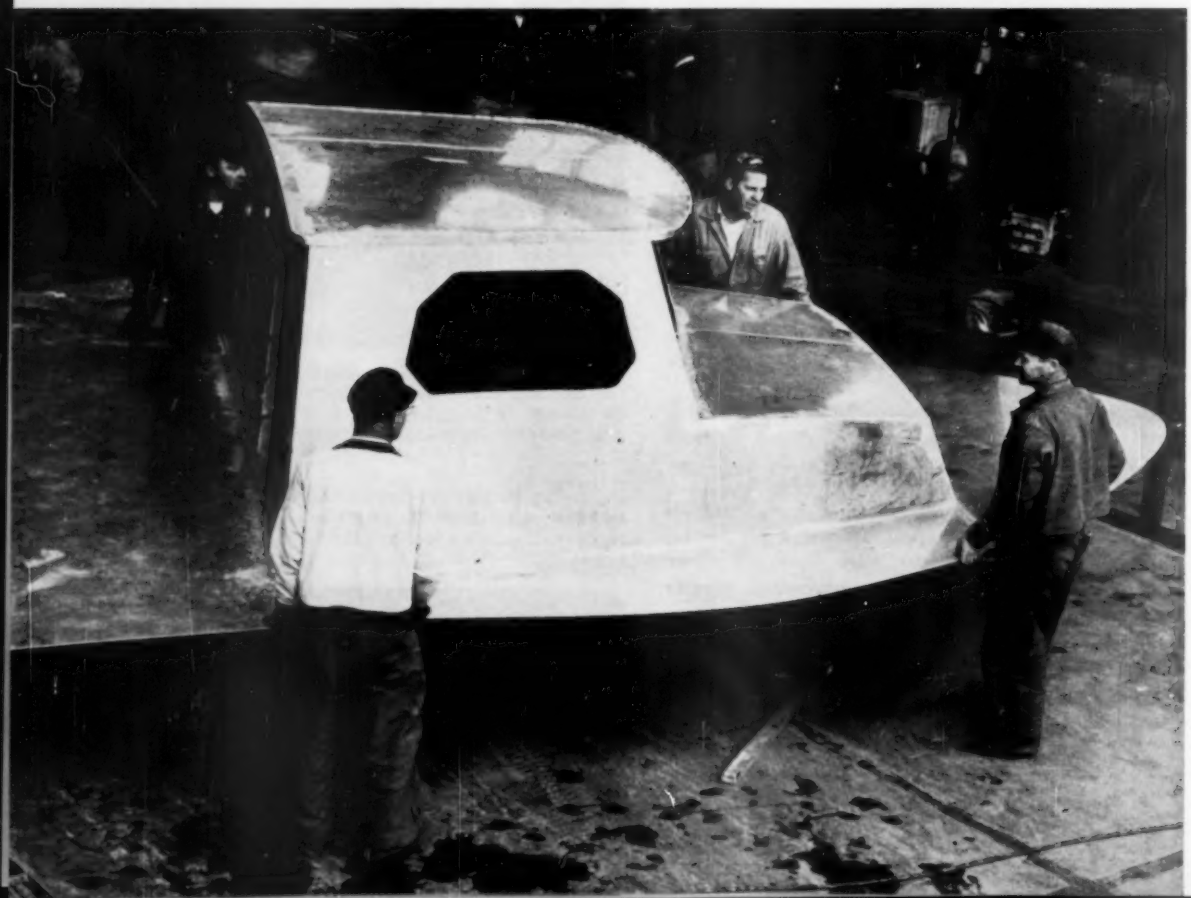
In addition to speed, which is important in Alaskan waters where the fishing season is short and fishing hours are regulated, load capacity, efficiency and quietness of operation were noted by fishermen who were aboard during test runs. The aluminum hulls are unpainted and will require no maintenance, affording substantial savings to the operator. Fishing boats of other materials require periodic surface repair including scraping and painting.

The boats are 32 ft long, with a beam of 11 ft 6 in. and a draft of 31 in. They are of all-welded construction, utilizing alloys 5086 (sheet) and 5083 (shapes) (see Fig. 2).

It is estimated that these boats are only two-thirds the total weight of other comparable boats. Fish capacity is about 27,000 lb each.

Each is designed for operation by two men who can sleep aboard if necessary. Equipment includes radio and galley.

Lightness of the deckhouses of the ten aluminum fishing boats is shown by the fact that four workmen easily lift and move a deckhouse by hand. The boats are all of welded construction, utilizing alloys 5086 and 5083



Joining Braided Wire to Heavy Casting "Couldn't Be Done" But...

BY CHUCK BASTION

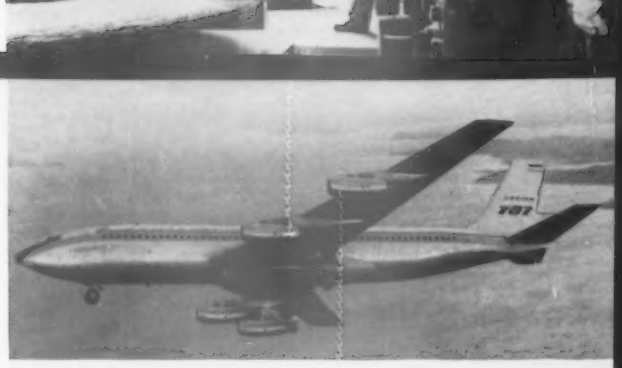


Fig. 1—One of the most complex commercial aircraft ever built, the Boeing 707 utilized the talents and imagination of many engineers and resulted in the perfection of new fabrication and manufacturing procedures

The problems confronting engineers in the design and construction of the now famous Boeing 707 (Fig. 1) were manyfold and complex. An airplane is not just two wings, a fuselage and a tail welded together; it is made of literally thousands of components, all of which must function correctly if the integrated result is to be successful.

One small but knotty problem was encountered by General Electric's Aircraft Service Department, subcontractors to Boeing, when engineers wanted to fabricate an electrical wiring harness to carry power to the landing-gear actuator motors of the "707" (Fig. 2).

The difficulty was to join flexible, spirally woven, stainless-steel conduit to cast stainless-steel fittings.

It was soon discovered that if enough heat was used to raise the stainless fittings to brazing temperature, the fine wires of the braided conduit would oxidize or "burn." A number of unsuccessful trials were made using silver-brazing alloys in the 1000 to 1500° F series. Apparently, what was needed was a strong alloy with high capillary action that would join stainless steel at low temperatures. Only in this way could the fine wires be joined to the cast fittings without damage.

A careful consideration of the available filler metals resulted in the choice of a particular tin-silver solder containing small amounts of copper and zinc, with a melting point of 430° F.

Conventional soldering procedures with their alloy produced a reasonably good joint, but not one of aircraft quality. A revised and successful method included tinning by dipping the fluxed parts into liquid solder at 450° F. To limit the tinning of the stainless fittings to joint surfaces only, other surfaces were marked off with soapstone. Tinned parts were assembled while hot and heated lightly with an oxyacetylene flame. Solder was added in wire form to make a fillet (Fig. 3).

Use of the tin-silver solder and procedure described previously produced joints which, in addition to withstanding 50,000-cycle flexure tests and conforming to rigid dimensional tolerances, were good for 2400-lb tensile load at 300° F.

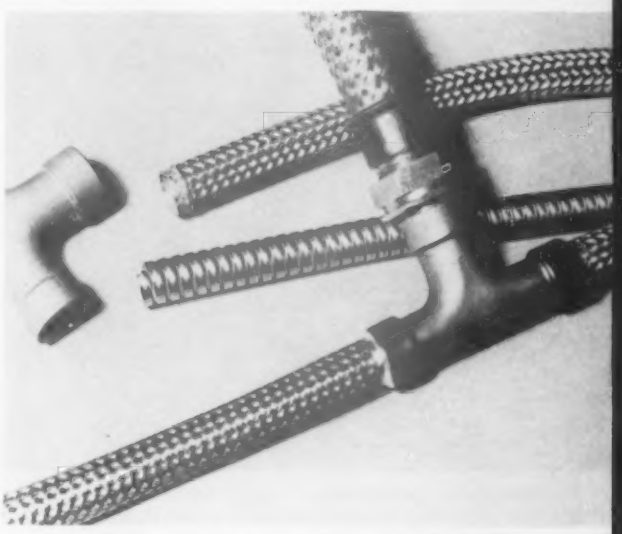


Fig. 2—This stainless-steel wiring harness supplies power to the actuator motors for the landing gear of the Boeing 707

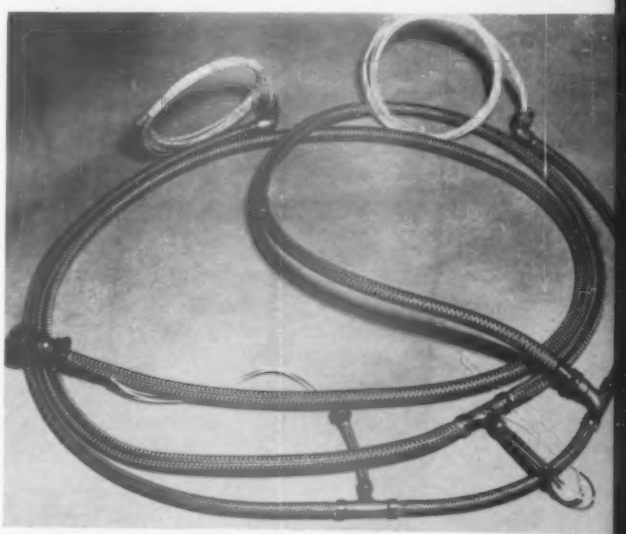


Fig. 3—A close-up of the joints in the wiring harness. The problem of joining woven conduit made of fine stainless steel wires to cast stainless fittings was solved by the use of a low-melting-point silver-tin solder and special tinning techniques

CHUCK BASTION, Regional Manager, All-State Welding Alloys Co. Inc.

Boosting the Vanguard Satellites

BY A. H. BUTLER, JR.

The third stage of the Vanguard rocket gives the final boost to send a satellite into orbit. Such was the case with Vanguard I, launched Mar. 17, 1958, and Vanguard II—the weather-eye satellite—placed in orbit Feb. 17, 1959.

The outside casing of the third-stage motor is made of 0.025-in. thick, Type 410 stainless steel and is fabricated by inert-gas tungsten-arc welding at Western Way Welding Co., Inglewood, Calif.

Roughly the shape of a giant capsule, the motor is 36 in. high, 18 in. in diameter and both ends are hemispherical in shape.

Assembly starts with the cylindrical center section clamped in the fixture and the hemispherical ends in position. Girth welds are made by manual tungsten-arc welding (Fig. 1). The fixture incorporates gas back-up and the rate of turning is controlled by a foot switch.

Exact centering and alignment of the nosepin is necessary in order to assure accuracy in flight. The pin is carefully aligned and tack welded. Then the finishing weld is made with a tungsten-arc torch (Fig. 2). All welds are shielded by 99.995% pure argon.

A completed rocket casing is shown in Fig. 3. The satellite, which is the payload, is fastened to the nosepin of the third-stage rocket motor. It is then cast off after burnout and left free in space.

A. H. BUTLER, JR., is Welding Sales Engineer, Linde Co., Los Angeles, Calif.

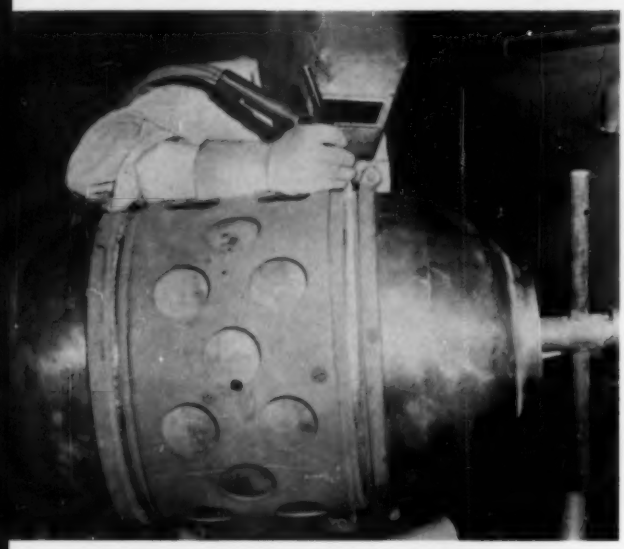


Fig. 1—An operator uses a tungsten-arc torch to weld the girth seams in the third-stage rocket casing for a Vanguard

Fig. 2—A tungsten-arc torch is used to join pin to special reinforcing plate in nose of this rocket casing

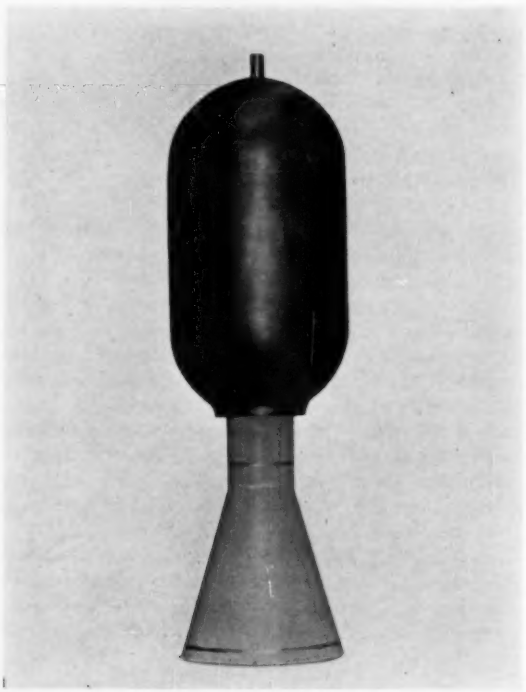


Fig. 3—A Vanguard Satellite will be attached to the pin on top of this third-stage rocket casing

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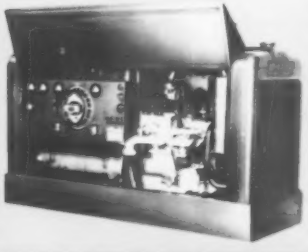

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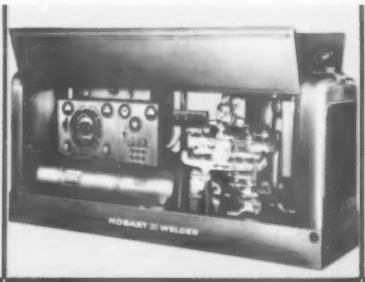

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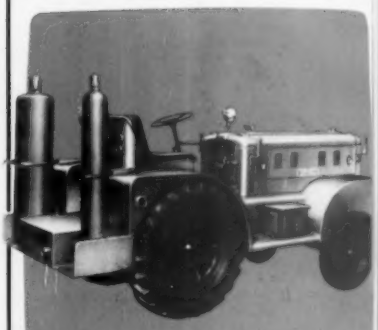

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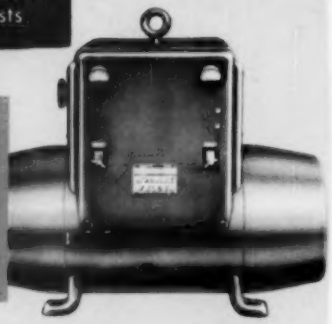

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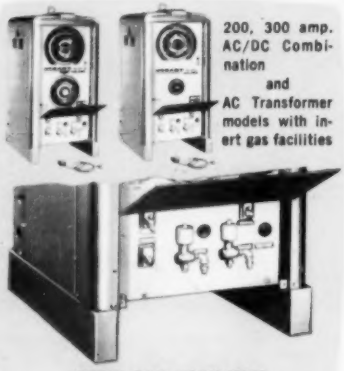

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Automation Makes the Difference

BY E. W. HOKANSON AND P. D. WADE

When a prominent midwestern manufacturer switched from manual welding methods to automatic submerged-arc welding, he achieved two invaluable improvements—a production increase of more than five times the previous rate, and improved product appearance that has decidedly increased consumer acceptance.

R. L. Faubion Co., Kansas City, Mo., is a leading producer of fuel and pressure tanks, and truck and tank trailers, both propane and gasoline.

Until a few months ago, Faubion's 300-gal farm fuel tanks, made of 12- and 14-gage mild steel, were fabricated with manual welding methods. The company had three objections: (1) with manual welding, one operator could only produce eight tanks per 8-hr day; (2) the manual welds required extensive postweld preparation prior to painting and lacked a smooth appearance; (3) the manual welds permitted a relatively high degree of leakage, requiring costly repair work.

This unhappy production picture was changed quickly, however, with the installation of three automatic submerged-arc welding machines, and a constant-potential power source. Welds are made with a current of 400 amp, 28 v, using submerged-arc welding flux and mild-steel wire.

Here is the production picture now. With a welding speed of 90 ipm on both the longitudinal and circumferential lap seams, one operator produces 45 tanks per 8-hr day—close to six times his previous rate. The smooth, uniform welds require little postweld preparation prior to painting. Also, leaks with submerged-arc welding are less than 10% as frequent as with manual welding methods—drastically reducing costly repair work.

Automation has made the difference!

E. W. HOKANSON is Executive Vice-President, R. L. Faubion Co., Kansas City, Mo., and P. D. WADE is Welding Sales Engineer, Linde Co., Kansas City, Mo.

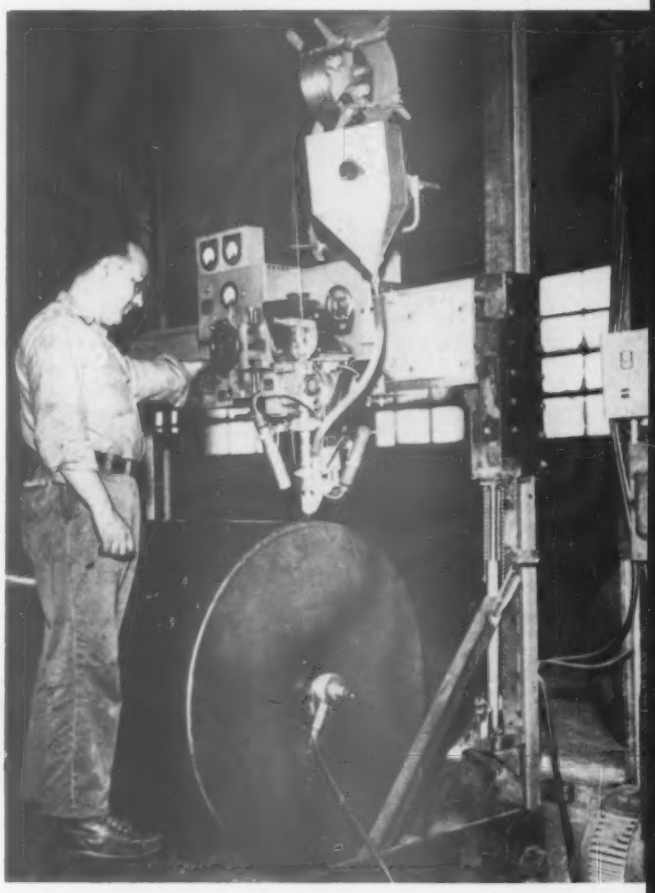
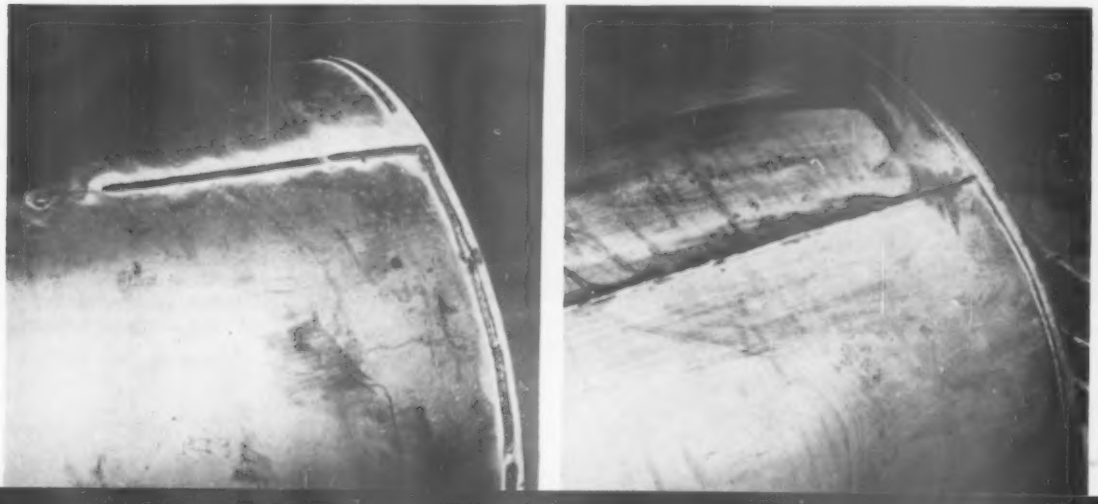


Fig. 1—Using an automatic submerged-arc welding machine, an operator begins a circumferential lap seam on a 300-gal fuel tank. One man now produces 45 tanks a day, six times his previous rate

Fig. 2—As different as night and day: compare the spotty manual welds (left) with the smooth, uniform automatic submerged-arc welds (right)



Society News

National Fall Meeting at Detroit a Success

Technical Papers Evoke Great Interest as First Fall Meeting in Three Years Is Convened

The registration desk is a busy scene as members get together for all-technical meeting held at the Sheraton-Cadillac Hotel in Detroit

Opening-day audience in the Grand Ballroom is impressed as Will Scott of the Ford Motor Co. forecasts sales of a million economy cars in 1960

The City of Detroit, famed as America's leading automotive center, played host to members of AWS, their friends and other interested observers who convened at the Sheraton-Cadillac Hotel from September 28th to October 1st for the fall technical meeting, first of its kind since 1956.

Although intended primarily for the presentation of the many first-rate technical papers which were given, the conclave boasted other features of interest and importance. Among these were the annual meetings of the three divisions of the Pressure Vessel Research Committee of the Welding Research Council and of its Executive and Main Committees, the Districts Council Meeting, the Section Officers Meeting, the Technical Council Meeting, the Educational Conference, a surprise TV program, the Board of Directors Meeting, a full Ladies' program of social activities, the Banquet held on Tuesday evening, plant tours and other activities.

Much credit goes to the AWS Detroit Section for the fine job done as host, and to the Arrangements Committee for their unsparing labor in making the affair a success.

After Convention Chairman A. E. Lindsey brought the meeting to order on Monday morning in the Grand Ballroom, AWS President C. I. MacGuffie welcomed his fellow-members, their wives and their guests to Detroit and the meeting was under way.

Automotive Industry Is Convention Theme

As pointed out by President MacGuffie in his opening address, this 40th Anniversary of the founding of AWS reaches a significant milestone at this meeting since it is the first to be devoted exclusively to the presentation and discussion of new investigations in the welding field and actions taken as a result.

This was followed by the keynote speech delivered by Will Scott, manager of the Ford Division Product Planning office who addressed the audience on the subject, "Economy Cars—The New Segment." This authoritative talk proved most timely and held special significance to the Detroit area whose economic welfare is so closely tied to the automotive industry.

Aptly, the keynote was picked up again in the emphasis given to automotive applications of welding which was featured on Tuesday when two complete technical sessions were given over to this field. The theme was further rounded out by the visit to that amazing industrial complex, the River Rouge Plant of the Ford Motor Co. at Dearborn, Mich.

Technical Sessions Center of Interest

By far, the greatest attraction of the 4-day meeting was the presentation in sixteen technical sessions of forty-eight papers covering original investigations and interesting applications on many different aspects of welding. Since all of these papers offered highly important information for some branch of the welding industry, and since no one individual could hear them all, copies were distributed of the "Abstracts of Technical Papers" which offered the opportunity of selection to those interested.

Educational Committee Arranges TV Program

The Educational Open Meeting, held on Wednesday under Acting Chairman H. S. Sosnin and Co-chairman E. Goehringer, was addressed by President MacGuffie and Vice-president Dave Thomas, both of whom emphasized the need for more education in welding. The object of the meeting was to help AWS sections with their educational problems.

A lively half-hour TV program was arranged at 6:00 P.M. Wednesday by courtesy of the "Wayne University Searchlight." Roy McCauley, head of welding engineering, Ohio State University, spoke on the subject of education for welding engineers. J. R. Stitt, of the R. C. Mahon Co., spoke on the value of the welding engineer to industry. President MacGuffie talked about AWS affairs. Their remarks have great significance to all members of AWS.

Other Sessions

The Technical Representatives,

President MacGuffie in his welcoming address predicted that this, the 40th anniversary year of the Society, will see the welding industry pass the billion-dollar mark

Will Scott traced the history of the compact car from the end of World War II to today's newest Ford product, the Falcon

The authors turn out for breakfast as Technical Papers Committee Secretary Bonney Rossi delivers last-minute instructions

T. W. Shearer, Jr. holds forth on "Design for Welding" as automotive welding is featured in one of Tuesday's technical papers session

held their meeting on Monday afternoon, with TAC Chairman J. J. McKinney presiding.

The Technical Council meeting was held Tuesday afternoon with R. D. Thomas as chairman.

Districts Council Meeting

Various questions which have arisen regarding local membership were discussed at the Districts Council meeting on Monday afternoon. In addition, the placement into sections and the status of membership of the two new states recently admitted to the United States—Alaska and Hawaii were also considered. National Secretary Fred Plummer addressed the group on the subject of raising funds for the new United Engineering Building for which the AWS is committed financially along with other engineering societies who will share the new quarters, due for occupancy sometime in 1961. Mr. Plummer stressed the valuable assets of prestige and utility.

Ladies' Program, Entertaining and Varied

A full program of social activities kept the ladies pleasantly entertained during their stay. On Monday, after a get-acquainted coffee hour, a trip was arranged to the Belle Isle Botanical Gardens, famed for their flower display. This was followed by luncheon at the "Roostertail" overlooking the Detroit River. Other trips on Wednesday and Thursday featured visits to the Henry Ford Historic Greenfield Village, where luncheon was served at Lovett Hall Foyer, and the beautiful Devon Gables with a stop-off later at the Cranbrook Institute.

Plant Tours

The Ford Motor Company's Rouge plant at Dearborn, Michigan, was visited on Wednesday.

On Thursday, a tour was conducted through the extensive plant of Canadian Bridge Works where large structural sections were in fabrication. The immense girders and bridge sections in process were ample evidence of Canada's rapid growth.

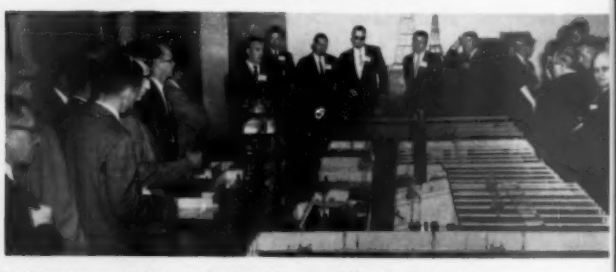
Banquet Offers Relaxation

Together with the cocktail hour on Tuesday evening, the banquet furnished a much welcomed change of pace. Chairman R. B. Wilcoxson welcomed the group on behalf of the Detroit Section of AWS. The George N. Sieger Memorial Award for the greatest over-all contribution to the Detroit Section was presented to Keith Sheren. Art Briese, nationally known humorist and after-dinner speaker provided the entertainment. Dancing followed until the wee hours.

Members and guests listen attentively as President MacGuffie addresses educational session

At the Section Officers-meeting, Assistant Secretary Frank Mooney reviews AWS headquarters activities. Vice-President Al Chouinard is the presiding officer

Members eagerly await the start of plant tour, as bus-load gets under way to Ford's River Rouge Plant



Visitors inspect the production layout of the Canadian Bridge structural shops, as Works Manager Neil Wallace points out features with the aid of small-scale model

The ladies obligingly pose during a morning coffee hour, before departing on a round of social activities. Chairladies in charge were Mmes. Lindsey, Kendall, Wolgast, Sheren, Wagner, Jones, Wilcoxson, Brown and Rainey

Other Meetings Held

The Section Officers' meeting was held on Tuesday morning.

The National Membership Committee held a breakfast meeting on Wednesday morning.

Also on Wednesday morning, a meeting was held by the Missiles and Rockets Welded Fabrication Committee.

Wednesday afternoon the AWS Bridge Subcommittee on Low-Alloy Steels held its session.

The Publicity Committee held its meeting also on Wednesday afternoon.

On Thursday morning, the Board of Directors convened and followed the meeting with the Board of Directors' luncheon at noon.

The Pressure Vessel Research Committee concluded its numerous meetings when the Executive and Main Committee Meeting was held on Friday morning. This terminated the National Fall Meeting of 1959.

Welcome Address

BY C. I. MACGUFFIE

AWS President, 1959–1960

Welcome to the first fall meeting of the AMERICAN WELDING SOCIETY to be held without an accompanying exposition.

This year of 1959 marks several important milestones along the course of our SOCIETY's growth.

1. It is the 40th Anniversary of our founding. During this past 40-year period, we have grown from an organization of about 200 individuals dedicated to the objectives of advancing the technology of the several then known welding processes, to an organization of about 13,000 individuals dedicated to the same objectives but now working with improved techniques covering over 80 different processes used in the joining of a greatly increased number of known metals and alloys.

2. This technical session will be the first National Technical Session devoted exclusively to the presentation and discussion of new problems in the welding field and action taken to solve them, that has not been supported by the income from and by the interest attraction of a supporting exposition. Our recent board of directors have felt that the rapid advance in the art and science of welding has mandated a second technical meeting of this type and magnitude to help speed the dissemination of our mushrooming fund of knowledge.

3. If present business forecasters are reasonably accurate in their predictions, 1959 will be the year in which the welding industry passes the billion dollar mark to take its place with many of the other billion-dollar industries that have made America the envy of the world.

I could name other significant milestones. It is my conviction that our new By-Laws which you approved finally in August will permit your elected officers to better

The members of the Board of Directors are hard at work at their meeting on Thursday morning. Facing the camera are National Secretary Plummer and President MacGuffie

The Pressure Vessel Research Committee holds its annual meeting, as Chairman T. N. Armstrong presides

The outstanding social event of the week was the banquet on Tuesday night, when lively entertainment and dancing followed an excellent dinner

keep pace with the increasing demands for action and progress in our SOCIETY's work activities.

In our technical sessions we will hear much this week about recent progress in the new metals, brought to us by the demands of atomic reactions and the many space vehicles in the laboratories and shops.

But it seems to me to be fitting and proper that this new step in technical meetings be held in Detroit the heart of the automotive industry. Progress in welding methods and products has assisted the automotive industry in its rapid rise to prominence as the United States' largest single industry. Automatic applications of welding have helped to keep costs in line with the public's pocketbooks. In turn, our members in the automotive industry have been heavy contributors to our SOCIETY's progress through their generous contributions of time and talents.

AWS has written a record over the past 40 years of which we can take great pride. It has contributed much to our country's industrial expansion not only in the automotive field, but in the chemical, oil, shipbuilding, railroad and the many other industries you know so well. It has an important role to play in accelerating its efforts to meet the demands of the new space age. Our greatest weakness lies in the limited trained manpower at our disposal to solve the vast number of new technical problems laid at our doorstep.

We must, therefore, concentrate during the coming years on doing a bigger and better job of education. When I think of this problem I think of its several phases.

One is the more rapid dissemination of technical information already discovered and developed through meetings such as this.

Another phase is the education of the engineers whose main field of professional activity lies in other areas, but who could make use of welding if they fully understood its role or its present state of development and reliability.

And last, but not least, is the problem of reaching the youths of our country in the high schools and early college years. We must get to them the true story of the many challenging opportunities that lie ahead of those that choose the welding industry as a career.

How well our organization carries this latter responsibility will determine how rapidly and how competently we can progress as a society and an industry in the years that lie ahead.

Bulletin from Hawaii

This has been a great year for the Hawaiian Islands. . .a history making year never to be forgotten. She's become a state—our country's 50th.

You will experience the throbbing excitement that surrounds our youngest state when you attend the American Welding Society's *First* Post-Convention Tour in Hawaii next April. In fact, excitement will be the basic element of your trip, from the moment you leave the West Coast aboard a luxurious airliner and until your return.

Your first stop—for two days—will be Kauai. . .full of natural wonders and curiosities, exotic mountain sculptures, wet and dry caves. . .and a surf "blowhole" that hurls a sixty-foot geyser in the air at every major wave. Kauai is the island first seen by Captain Cook. With his landing in 1778, the arrival of the Old World civilization began the modern history of Hawaii. Cook named them The Sandwich Islands—honoring his sponsor, the Earl of Sandwich.

As you land, leis will lend brilliance to your arrival at Kauai. You will most likely receive a Mokihana Lei. The Mokihana is the berry found only on Kauai Island.

Everyone in the world knows that the word lei is Hawaiian for garland. Hawaiians believe in "saying it with flowers". . .and they do. . .with the Ginger Lei, or Plumeria, or Jasmine, or Gardenia.

In the early days of Hawaii the lei was always made of feathers. It was the special mark and prerogative of royalty. Gradually, as the Island birds which furnished the feathers became rare and even extinct, Island flowers came naturally to be substituted.

Frank S. Mead, renowned traveler and lecturer, has said—

> "When God made the Hawaiian Islands, he used the best he had; he left it an earthly paradise. Spend a day there and you weep when you leave—and there is something deeper than the strain of Aloha Oe, sung by the Hawaiians as you leave, that makes you weep."

In short—it's an EARTHLY PARADISE with ALL of the BEST!

● ● ● ●

Watch for a complete itinerary of the American Welding Society's first post-convention tour in Hawaii . . . in next month's Welding Journal.

Who's who?

The Who's Who in Welding read* THE WELDING JOURNAL. *The Journal is required reading for more than 50,000 potential buyers . . . key men in their respective fields . . . representing the largest concentration of purchasing power in the metal-fabricating world.*

* *These are the people who buy and influence buying of welded products.*

AN INVITATION TO AUTHORS

—to participate in the American Welding Society's

1960 NATIONAL FALL MEETING

Pittsburgh, Pa.—September 26-30, 1960

Gentlemen:

The 1960 National Fall Meeting of the AMERICAN WELDING SOCIETY will be held in Pittsburgh, Pa., on September 26–30.

Each year our SOCIETY offers opportunities to authors for bringing their outstanding work, development and research to the attention of our membership and the welding and metals industry, by having previously unpresented and unpublished papers presented at its national meetings.

The SOCIETY's Technical Papers Committee will be happy to receive your application for entry in the 1960 National Fall Meeting activity. All applications, abstracts and manuscripts will be screened by the committee, and authors will be notified sometime in April 1960 regarding acceptance.

Each abstract should be sufficiently descriptive to give the committee a clear idea of the content of the proposed paper. In any case, it must contain *not less than 500—but preferably not more than 1000—words.* Also, in order to place the committee in the best possible position to evaluate these papers, it is suggested that each abstract be accompanied by a complete manuscript.

The committee reserves the right to consider all applications on the basis of acceptance for placing on the 1960 Fall Meeting program, or consideration for placing on the program of the succeeding national meeting of the SOCIETY, the 42nd Annual Meeting. Papers may be considered for publication in the WELDING JOURNAL regardless of acceptance for presentation at either meeting.

Papers dealing with latest developments in (1) welding in mill practice; (2) fabrication and maintenance of equipment used for radioactive applications; (3) pressure vessels and storage tanks; (4) equipment and pipe lines used in petroleum industry; (5) design and fabrication of all types of weldments, including machinery; (6) structures; (7) automation as applied to welding processes; (8) resistance spot, seam and projection welding; (9) gas-shielded arc welding; (10) new processes; (11) welding of castings and composite structures; (12) welding of "new" alloys; (13) weldability of high-strength steels; (14) welding of aluminum, magnesium, zirconium, titanium, molybdenum and like metals; (15) welding of aircrafts and rockets; (16) brazing; (17) maintenance; (18) surfacing; (19) soft soldering; (20) adhesive bonding; (21) welding of plastics; and (22) practical applications or "how-to-do" topics are deemed to be of particular interest at the Pittsburgh meeting. However, any papers dealing with the educational and informative categories of welding production, engineering, research and metallurgy, are welcomed as long as the subject falls within the field of our SOCIETY's activities.

Author's Application Forms have been mailed to all members of our SOCIETY; additional copies may be obtained by writing directly to AWS headquarters. In order to be considered for the 1960 Fall Meeting program, abstracts must be postmarked not later than January 15, 1960.

Sincerely,
Fred L. Plummer
National Secretary

JOIN AWS...

. . . and help build yourself a better future through a stronger and more prosperous welding industry. Grow with the industry and progress with AWS.

Your membership brings you these advantages:

- Welding Journal—The World's outstanding welding engineering and application magazine comes to you each month.
- Welding Handbook—The "Bible" of the welding industry—Full Members receive a new 500 page section each year.
- Section Activities—Each month you join other Section Members in meetings, plant tours, educational courses, social and recreational activities: greeting the experts, interchanging ideas, learning new welding know-how, enjoying fellowship and having good fun.
- National Activities—Annual Meetings, the Welding Exposition, more than one hundred technical and operating committees provide opportunities for your national participation.
- Welding Standards—You can help develop the manuals, codes and specifications used nationally and internationally to control welding and welded fabrication.

Why not join AWS now? For application form and additional details, write:

AMERICAN WELDING SOCIETY, INC.

33 WEST 39th STREET • NEW YORK 18, N. Y.

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	C. M. Styer	C. E. Jackson	C. B. Smith
		J. L. York	J. R. Stitt

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J. J. Chyle G. O. Hoglund C. P. Sander

Long President of AIME

Carleton C. Long, of Monaca, Pa., Director of Research, St. Joseph Lead Co., has been elected president of the Metallurgical Society of the American Institute of Mining, Metallurgical, and Petroleum Engineers. He will take office during the Annual Meeting of the Institute, to be held Feb. 14–18, 1960, in New York City. Dr. Long will succeed John Chipman, head of the Department of Metallurgy, Massachusetts Institute of Technology. The term is one year.

J. S. Smart, Jr., of New York City, general sales manager, American Smelting and Refining Co., has been named vice-president of the Metallurgical Society and its president-elect, slated to take office as president in 1961, following Dr. Long's term. Mr. Smart also has been elected to a three-year term on the AIME Board of Directors.

Welcome

• Sustaining Member

Dockson Corporation, Detroit, Mich.

This company was established in 1923 and has specialized in the manufacture of oxyacetylene welding equipment and head and eye protective equipment. Among its products are welding, cutting, and heating torches; pressure regulators; welding and safety goggles and spectacles; welding helmets; face shields. Replacement lenses, welding plates, tank and hose connections and other accessory items for use in the welding and industrial safety equipment field are stocked for a distributor organization throughout the country and for the export trade.

H. E. Piggott is the sustaining member representative.

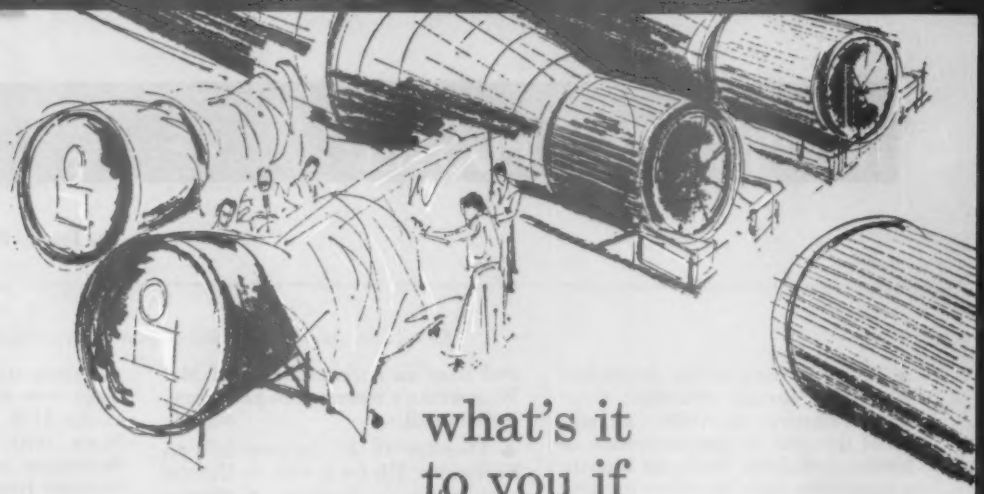
• Supporting Companies

Effective Sept. 1, 1959

C. E. Phillips & Co.,
2750 Poplar St.
Detroit 8, Mich.

Kerrigan Iron Works Co.,
1033 Herman St.,
Nashville, Tenn.

For details, circle No. 10 on Reader Information Card →



what's it to you if P&H is 75 years old?

Some companies put on years with momentum — the older they get, the faster they move. Harnischfeger Corporation — familiarly known by its trademark as "P&H" — is like that.

Over the years many P&H products have been fabricated by welding. That's how we got into the welding business: nobody else had yet built machines that welded the way we wanted, so we made a better machine than those available.

... And shared it with industry.

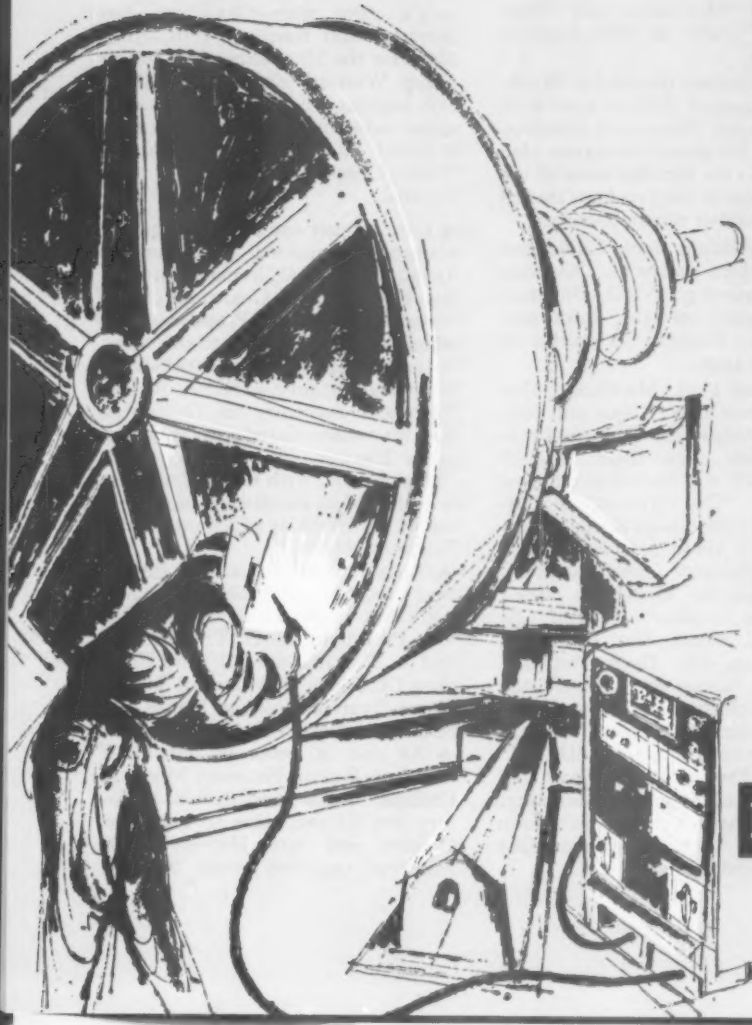
Same with electrodes: We wanted better chemistry, greater tensile strength, finer welding characteristics for fabricating our power shovels and overhead cranes, so we made them ourselves.

... And sold them to you.

When we searched for a more efficient method of weldment handling, we started making welding positioners, and we built them better than anything similar on the market.

The point is this: our welding products are the payoff on 75 years of actual metal fabrication experience. Each one—welders, electrodes, and positioners — has been tested and proved in actual production-line experience before being sold to industry. And each product has been made with the kind of quality that is bounded on the north by craftsmanship and on the south by satisfaction.

Isn't that the kind of assurance you want on your next welding purchase?



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...quality and service for 75 years

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KEEPING YOU POSTED

by Fred L Plummer

● The June issue of the *Australian Welding Journal* included three items referring to AWS: an editorial devoted to our promotion of National Welded Products Month; a letter from your Secretary inviting Australians to participate in our Mid-Pacific Conference to be held in Honolulu May 3–4, 1960; and an article outlining the suggestions issued by the editor of our JOURNAL to aid in the preparation of papers offered for publication.

● The Executive group of EAC met in Philadelphia in August to plan the all-day educational conference held at our fall meeting in Detroit and to outline short specialized courses covering new processes, construction in special fields such as missiles, aircraft and atomic power plants, training, testing, safety and many others to be offered to graduate engineers by those best qualified to present the newest developments. The first course is planned for early spring.

● Brochures describing our Mid-Pacific Conference and Hawaiian Tour were distributed at the meeting in Detroit. Elsewhere in this issue of the JOURNAL you will find a first article devoted to these events. The December issue will include another article and you will probably soon receive a brochure with your hotel form for the Annual Meeting and Welding Exposition in Los Angeles. Plan to join fellow AWS members in what promises to be an unusually gay and happy adventure.

● The October issue of the JOURNAL brought you a picture of statistics about, and reasons why, AWS is establishing your national headquarters in the new United Engineering Center. Plans were also outlined for your participation. The accompanying table shows the quota established for each Section. Help your officers by giving cheerfully and generously. Insure that your Section will be one of the first to exceed its quota.

● Late summer mail included a card from Rene Wasserman sent following the IIW Assembly in Yugoslavia and later an announcement of Mr. Wasserman's marriage in Lausanne, Switzerland.

● Director C. E. Jackson left on September 4th for a visit to Europe with stops in England, Germany and Russia.

● Past-President Joe Humberstone flew to Europe on September 23rd for a six-week business trip. During part of this time he will be joined by Airco President J. A. Hill and Arcrods Director of Research Jerry Claussen.

● Staff Members Frank Mooney and Art Phillips visited Detroit August 24th to complete arrangements for the National Fall Meeting and plan special publicity features including a half hour broadcast with Prof. Roy McCauley and Engineer Ray Stitt as the featured performers.

● Your Secretary traveled to Washington on August 28th to meet with Trustee Frank Davis and Administrators of the group insurance plan described in the October issue of the JOURNAL and in the brochure mailed to each member during October.

● Past-President Jack Chyle and your Secretary met with Chairman Tom Armstrong, WRC Directors and members of the important Interpretive Reports Committee on September 10th.

● President C. I. MacGuffie, District Director J. W. Kehoe and your Secretary helped the Niagara Frontier Section open their 1959–60 season with a "National Officers' Night" at "The Cypress" in Buffalo. Chairman John Kaluzny presided as all three national officers discussed SOCIETY plans and activities—President MacGuffie being the feature speaker. Section officers W. L. Burch, Don Campbell, Sam Corica, Jim Russ and old-timer Bob Siemer each contributed to the carefully planned and well attended dinner meeting. It was a joy to meet and chat with "Is" Morrison, Fred Brown, August Clemens (new manager of a Westinghouse department in Buffalo), John Lang (on a temporary assignment at AMF) and many others.

● Lunch the following day in New York was devoted to a discussion of the IIW 1961 Assembly in New York with WRC Director Bill Spraragen and IIW Past-President Howard Biers.

● September 22 was a busy committee day with your Technical Papers Committee under Chairman Tom Armstrong and Secretary Bonny Rossi selecting papers for the annual meeting in Los Angeles next April; a meeting of U. S. representatives on IIW Commission IX at the call of Chairman R. W. Vanderbeck; and a meeting of the American Council of IIW with more than fifty members in attendance.

● The following day your Exposition Committee met in your Secretary's office with Chairman Jim Norcross and members completing plans for the 1960 Exposition in the Great Western Exhibit Center in Los Angeles, April 26–28. Advance space sales indicate that this first national all-welding show on the West Coast will establish new records.

● Late August and early September visitors at national headquarters included Harvel Gillerman, Director Jay Bland who is Chairman of our Awards Committee, President C. I. MacGuffie for a full half-day conference, Treasurer H. E. Rockefeller following his July vacation, former Technical Secretary Si Greenberg who is now associated with Westinghouse Electric, Ned Nyberg, C. B. Voldrich who, with G. E. Faulkner, is author of an excellent interpretive report on "Welding of Titanium and Titanium Alloys."

● Telephone conferences on important SOCIETY activities were held with Past-President G. O. Hoglund, Vice-Presidents R. D. Thomas, Jr., and A. F. Chouinard, Public Relations Chairman H. Morrison, Travel Agent Ryan of Holliday House and SOCIETY Attorney Holloway.

● As this is being written Staff Members Fenton, Krisman, Mooney, Phillips, Rossi and your Secretary are all preparing to leave for Detroit and our National Fall Meeting, the first event being a

455 King St. West • Toronto, Ontario, Canada.

luncheon meeting of the Arrangements Committee on Sunday, September 27th, with Detroit chairmen as follows: A. E. Lindsey, J. E. Rainey, C. R. Hildebrand, K. Sheren, R. B. Chatterton, C. Schamanek, R. P. Wolgast, L. R. Broniak and W. A. Jones.

● On October 5th John Tierney joined our technical department as an assistant to Secretary Ed Fenton.

Contributions to United Engineering Center Building Fund as of Sept. 1, 1959

Local Section	Quota	Pledged	Quota, %
District 1	**$ 4,900**		
Boston (1)[a]	1,800	$ 150	8
Bridgeport	400	...	..
Hartford (2)	700	175	25
New Hampshire	200	...	..
Northern N. Y. (1)	600	15	2
Providence (1)	700	3	..
Western Mass.	200	...	..
Worcester	300	...	..
District 2	**$12,800**		
Carolina (1)	300	50	17
Lehigh Valley (1)	800	25	3
Long Island	800	...	..
Maryland (2)	1,000	550	55
New Jersey (2)	2,600	530	20
New York (6)	2,600	1620	62
Philadelphia (12)	2,800	2450	88
Richmond	400	...	..
Susquehanna	400	...	..
Washington, D.C.	500	...	..
York-Central Pa. (1)	600	60	10
District 3	**$ 5,900**		
Mahoning Valley	700	...	..
Mohawk Valley	100	...	..
Niagara Frontier	1,200	...	..
Northwestern, Pa.	400	172	43
Olean-Bradford	200	...	..
Pittsburgh (4)	2,400	...	..
Rochester (1)	500	100	20
Syracuse	400	...	..
District 4	**$ 3,400**		
Baton Rouge	400	...	..
Birmingham (1)	600	120	20
Chattanooga	200	...	..
Holston Valley	200	...	..
Mobile	300	...	..
Nashville	300	...	..
New Orleans	400	...	..
Northeast, Tenn. (1)	300	100	33
Pascagoula	200	...	..
South Florida	400	...	..
Tri-Cities	100	...	..
District 5	**$ 6,200**		
Cincinnati (9)	600	147	25
Cleveland (1)	2,400	15	1
Columbus	800	...	..
Dayton (6)	600	355	59
Indiana (1)	600	50	8
Louisville	300	...	..
North Central Ohio	400	...	..
Stark Central	500	...	..
District 6	**$ 4,400**		
Anthony Wayne (1)	200	$ 50	25
Detroit (2)	2,700	150	6
Saginaw Valley	600	...	..
Toledo	500	...	..
Western Mich.	400	...	..
District 7	**$ 6,700**		
Chicago (1)	2,500	25	1
Eastern Illinois	200	...	..
Fox Valley	500	...	..
Iowa-Illinois (1)	400	30	8
J.A.K.	300	...	..
Madison	400	...	..
Michiana	300	...	..
Milwaukee (2)	1,400	150	11
Peoria	400	...	..
Sangamon Valley	300	...	..
District 8	**$ 3,400**		
Colorado	400	...	..
Iowa	300	...	..
Kansas City	500	...	..
Nebraska	200	...	..
Northwest	900	...	..
St. Louis	800	...	..
Wichita	300	...	..
District 9	**$ 3,900**		
Houston (1)	2,100	10	..
North Texas	600	...	..
Oklahoma City	300	...	..
San Antonio	400	...	..
Shreveport	200	...	..
Tulsa	300	...	..
District 10	**$ 4,300**		
Albuquerque	200	...	..
Arizona	200	...	..
Long Beach	500	...	..
Los Angeles	2,900	...	..
San Diego	500	...	..
District 11	**$ 4,100**		
Portland	500	...	..
Puget Sound (1)	800	7	1
Salt Lake City	600	...	..
San Francisco	1,300	...	..
Santa Clara Valley	900	...	..
Totals	**$60,000**	7109	12

[a] Number of pledges shown in parentheses.

EDUCATIONAL ACTIVITIES

National Welded Products Month

Education is not confined to any one subject or any one public, it embraces all knowledge and all people. Keeping the general public informed of welding activities is just another facet of education.

Last year, for the first time, the AMERICAN WELDING SOCIETY sponsored April as National Welded Products Month. People all over the country learned more about welding in the space of four short weeks than they had previously learned in the whole of their lives.

All over the country newspapers carried news and pictures of governors and mayors signing proclamations proclaiming April as National Welded Products Month. Department stores used the opportunity to provide window displays of welded appliances. Welding equipment and welded machinery were displayed in the main squares of various cities. The amount and number of displayed welded products was only limited by the zeal and enthusiasm of the representatives of the AWS sections.

The illustrations on this page give an indication of the cooperation possible for the promotion of National Welded Products Month. The pictures are representative of the many displays which were made in various parts of the country last April.

This coming April can make more people than ever aware of welding and the part it plays in their daily lives, if an earlier start is made. Publicity committees should be formed as soon as possible and arrangements should be made to contact governors and mayors to make preparations for the signing of proclamations at a later date.

This year's objective is 50 governors and the mayor of every town.

A display in Sears, Roebuck, Saginaw, Mich.

Many people saw this display at Kresge's store, Saginaw, Mich.

This window display of welded products in South Bend, Ind., was continued for four weeks in April last year

Planning Manual

Last year a Planning Manual was prepared for the guidance of sections and many section publicity representatives used it to advantage. This year a more comprehensive manual will be available which will be of even more use, since last year's experiences have shown what additional material was needed.

Free Information

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Free Literature

•

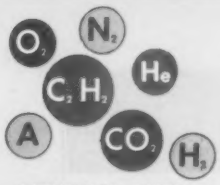
"YOURS FOR THE ASKING"

•

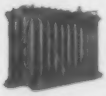
Use Reader Information Card

•

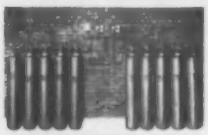
Page 1151



INDUSTRIAL GASES



SUPPLIED IN CYLINDERS, PORTABLE BANKS, STATIONARY UNITS TRAILERS, LIQUID CONVERTERS



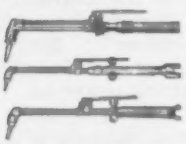
MANIFOLDS AND CONTROL UNITS

PRESSURE COMPENSATING REGULATORS

DUAL-STAGE REGULATORS

SINGLE-STAGE REGULATORS

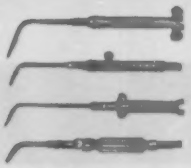
CUTTING TORCHES



CUTTING ATTACHMENTS

MACHINE CUTTING TORCHES

CUTTING TIPS



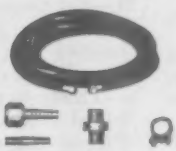
WELDING AND BRAZING TORCHES

WELDING AND HEATING TIPS

GAS WELDING FILLER RODS

COMBO KIT

GASARC* TORCHES



GAS HOSE AND HOSE FITTINGS

CYLINDER TRUCKS

TIP CLEANERS

WELDING AND BRAZING FLUX

GOGGLES AND EYE SHIELDS

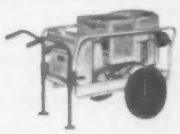
HELMETS

GLOVES

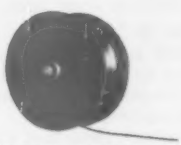
WELD CLEANING TOOLS

ELECTRODES

AC WELDERS, AC-DC WELDERS, DC WELDERS INERT GAS ARC WELDERS



PORTABLE WELDERS



WELDING WIRES (SPOOLED & COILED)

PORTABLE SPOT WELDERS

NCG

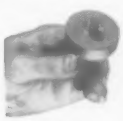
... welding, cutting, brazing, and metal conditioning

AUTOMATIC WELDING EQUIPMENT

ELECTRODE HOLDERS

CABLE AND CONNECTORS

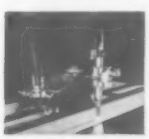
GROUND CLAMPS



CENTER-FIXERS

ANGLE HOLDERS

TYPE R CUTTING MACHINE AND ELECTRONIC LINE TRACER

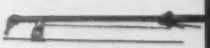


CUT-O-MATIC* PORTABLE CUTTING MACHINE

WELDING, CUTTING, FLAME HEAT TREATIN PORTABLE CARRIAGE

FLAME CLEANING

FLAME HARDENING EQUIPMENT



SCARFING TORCHES

POWDER CUTTING EQUIPMENT

ACETYLENE GENERATORS

HYDROPURE* GAS PURIFIERS

CONTINUOUS RAIL WELDING EQUIPMENT

ABRASIVE BELT RAIL GRINDER

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NATIONAL CYLINDER GAS

DIVISION OF CHEMETRON CORPORATION

CHEMETRON

840 NORTH MICHIGAN AVE., CHICAGO 11, ILLINOIS

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Circle No. 11 on Readers' Service Card

SECTION NEWS AND EVENTS

As Reported to Catherine M. O'Leary

Colorado

TUNGSTEN-ARC WELDING

Denver—The *Colorado* Section held its September meeting on the 8th at Cavaleri's Restaurant. The group gathered at 6:30 P.M. for appetizer until 7:00 when dinner was served.

At 8:00 P.M. the speaker of the evening took over. He was Roy Palan of the Welding Development and Research Department of the Dow Chemical Co. at Rocky Flats. His subject was "A Special Application of Tungsten-arc Welding of Aluminum." During his talk he told how to weld aluminum caps or aluminum slugs of $^1/_4$ in. thickness to base metal $^1/_8$ in. thick. Also, he explained that sine square wave works best for welding with helium, argon mixture and tungsten electrode. An unusual film, in very slow motion, showed the different types of arcs. This was very interesting.

Iowa

CUTTING

Des Moines—The first regular meeting of the new season of the *Iowa* Section was held Sept. 17, 1959, at the Kirkwood Hotel. It was attended by 50 members and guests, who had the pleasure of hearing Ray W. Johns of the Linde Co., Kansas City Division, speak on oxy-natural gas and inert-gas tungsten-arc cutting.

Mr. Johns started his talk with a short discussion of the new products developed especially for oxy-natural gas cutting and their proficiencies. This was followed by a question-and-answer period. The speaker then went on to discuss the relatively new process of inert-gas tungsten-arc cutting of ferrous and nonferrous materials. This subject was received with a great deal of interest, as shown by the type and number of questions during and immediately following Mr. Johns' presentation.

Michigan

POWER SUPPLY

Detroit—The *Detroit* Section initiated its 1959–60 program with a special technical meeting on Thursday, Sept. 10, 1959, at the Engineering Society of Detroit's Rackham Foundation Building.

Thirty-five members and guests heard Ralph Mertz of the Detroit Edison Co. discuss "Utility Power for Resistance Welders." Mr. Mertz covered various problems encountered in supplying power for resistance welding. He explained the somewhat unusual methods of charging for this power, which is not satisfactorily measured by standard metering equipment. Emphasis was applied to "cyclic flicker" as it is associated with lighting and welding power on common circuits. Local requirements covering users connection to utility lines, line capacity, substation location, etc., were explained.

New Jersey

WELDING THE "TRITON"

Newark—"Welding of the World's Largest Undersea Craft, the Atomic Submarine *Triton*" was the subject of the *New Jersey* Section's opening meeting of the season held on September 15th

SECTION MEETING CALENDAR

DECEMBER 2

OKLAHOMA CITY Section. Dinner meeting. Swyden's Restaurant. Speaker H. F. Reid, The McKay Co.

TULSA Section. Codes and Inspection.

SUSQUEHANNA VALLEY Section. Dinner meeting 6:45 P.M. Foot Hills Manor, Shickshinny, Pa. "Welding Research at Watertown Arsenal Labs.," Carl E. Hartbower, Watertown Arsenal.

DECEMBER 3

DETROIT Section. Special technical meeting. 8 P.M. Engineering Society of Detroit, Rackham Bldg. Gas-Shielded Metal-Arc Welding.

IOWA-ILLINOIS Section. American Legion, Moline, Ill. 7:00 P.M. to 1:00 A.M. Annual Christmas Dinner Dance.

NIAGARA FRONTIER Section. Plant visit—Harrison Radiator Co., Lockport, N. Y. Dinner and meeting at Lockport Park Hotel.

DECEMBER 5

ST. LOUIS Section. Annual Ladies Night—Dinner and Dance. George Johnson's KMOX-TV Studio Orchestra. Norwood Hills Country Club.

DECEMBER 8

BIRMINGHAM Section. Salem's Number Two Restaurant. Social 6:30 P.M. Dinner 7:00 P.M. Meeting 8:00 P.M. Joint AWS and ASM Meeting. "Why Welding Fails" Helmut Thielsch, Grinnell Corp.

DAYTON Section. Welding—Its Application to Rockets.

NEW YORK Section. Victor's Restaurant. Dinner 6:15 P.M. Meeting 7:15 P.M. Sustaining Members Night—"What the Future Holds for Welding." Panel discussion headed by President C. I. MacGuffie.

North Texas Section. Western Hills Inn. 6:30 P.M. Dinner and Technical Session.

DECEMBER 10

J. A. K. Section. Joliet, Ill. Social Program.

PUGET SOUND Section. Annual Christmas Party.

DECEMBER 11

CHICAGO Section. 5th Annual Christmas Party. Dinner and Dancing starting 6:30 P.M. Martinique Restaurant, Evergreen Park.

DETROIT Section. Annual Company Night. Weltronic Company plant. 7 P.M.

MILWAUKEE Section. Ambassador Hotel. 6:30 P.M. "Welding High-Strength Low-alloy Steels" Ernest H. Franks, Electric Boat Div., General Dynamics Corp.

PHILADELPHIA Section. Naval Architects Night. "Design and Fabrication of Heavy Pressure Vessels for Nuclear Applications," H. Kraig, M. Willis and R. Bradway, New York Shipbuilding Corp.

DECEMBER 12

FOX VALLEY Section. Van Abel's, Hollandtown, Wis. Christmas Dinner Dance.

DECEMBER 15

NEW JERSEY Section. Essex House, Newark Dinner 6:30 P.M. Meeting 8:00 P.M. "Welding Precipitation-hardening Stainless Steels," George E. Linnert, Armco Steel Corp.

TOLEDO Section. Toledo Yacht Club, Bayview Park. Dinner 6:00 P.M. Meeting 8:00. "Pressure-vessel Fabrication for Nuclear Service," Wm. R. Apblett, Foster Wheeler Corp.

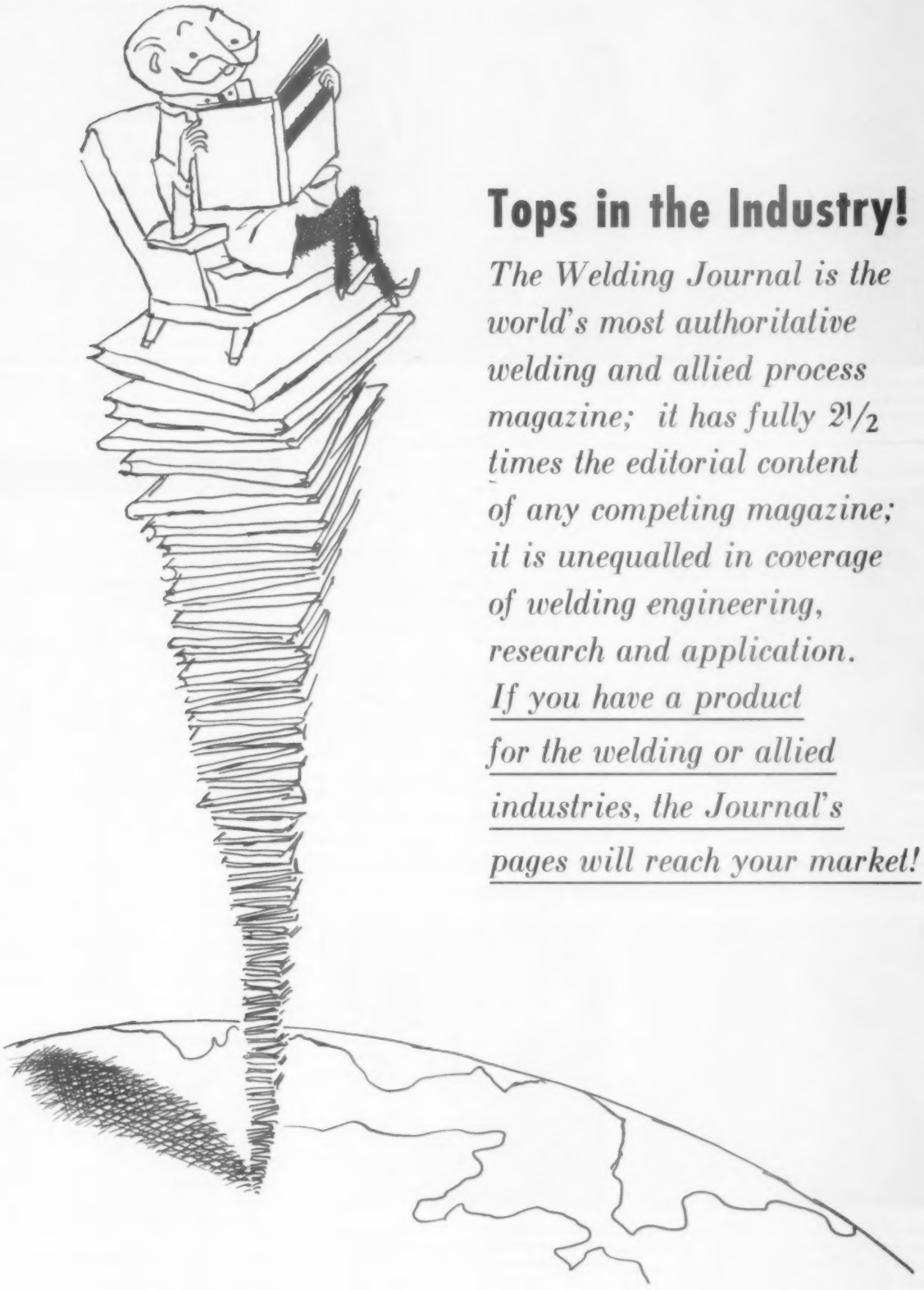
DECEMBER 17

MADISON Section. Beloit, Wis. "Control and Correction of Distortion in Steel Weldments," LaMotte Grover, Air Reduction Sales Co.

DECEMBER 18

INDIANA Section. Tour of Naval Avionics, Indianapolis.

Editors Note: Notices for February 1960 meetings must reach JOURNAL office prior to November 20th, so that they may be published in the January Calendar. Give full information concerning time, place, topic and speaker, for each meeting.



Tops in the Industry!

The Welding Journal is the world's most authoritative welding and allied process magazine; it has fully 2½ times the editorial content of any competing magazine; it is unequalled in coverage of welding engineering, research and application. If you have a product for the welding or allied industries, the Journal's pages will reach your market!

NEW OFFICERS OF J.A.K. SECTION

The officers of the J.A.K. Section for the 1959-60 season are, left to right, back row; R. Lincoln, E. Hutton, J. Wolf, A. Gerl and R. Barnet. In the front row, same order, are P. Vanderploeg, Wm. Matosovic, R. Liclecka and M. Sumter

DISCUSSES POWER SOURCES

Utility power for resistance-welding machines was discussed by Ralph Mertz at the September 10th 10th meeting of Detroit Section

at the Essex House in Newark, N. J. George W. Kirkley of Electric Boat Division, General Dynamics Corp., Groton, Conn., discussed some of the many problems involved in the construction of atomic submarines, and described the special welding techniques which were developed for fabricating certain components.

Mr. Kirkley showed how the hull section subassemblies are fabricated, and joined to other hull sections, starting amidships and proceeding simultaneously toward both ends from the center. The internal framing of the vessel is installed as the hull cylinders are attached. Fabrication of the Triton, which is the largest of the atomic submarine fleet, and 100% welded construction, consumed 350,000 lb of covered welding electrodes alone.

The speaker described the "surgically clean" conditions required in areas where piping assemblies and other critical components are welded. To help attain these clean conditions, the interior walls of the building are vacuum-cleaned twice a day, and a positive pressure is maintained within the building to exclude dust.

A color sound movie demonstrated the use of the consumable-weld-insert ring developed for joining pipe for the atomic submarines. This film, which contained sequences photographed at ultra high speed, showed how the weld inserts are fused in and drawn up into the root of the weld to provide a smooth weld on the inside of the pipe, free of harmful crevices or notches.

WELDING OF ATOMIC SUBMARINE IS DESCRIBED

George W. Kirkley addressing the opening meeting of the New Jersey Section on September 15th. His topic was the welding of the Triton, the largest atomic submarine

Section Chairman H. L. Hoffman presented a souvenir plaque to Mr. Kirkley, in appreciation of his contribution

New York

BRAZING

Hicksville, N. Y.—The *Long Island* Section met for dinner and meeting on September 10th at Hennigsen's Restaurant. The speaker of the evening was D. E. Herrschaft, assistant manager, Brazing Products Div., Handy & Harman, New York. His topic was "Brazing Challenges the Thermal Barrier." The talk covered the problems of producing good brazes for elevated-temperature service, with particular emphasis on applications in the aircraft industry, both for engine construction and airframe construction (honeycomb). Current problems on the B-70 and F-108 were discussed. The talk was concluded with a prediction of where the "super" brazing alloys of tomorrow may be obtained. Interest in the subject was so great that the subsequent discussion period exceeded the time the speaker spent on his initial delivery.

RESISTANCE WELDING

New York—The 1959-60 season of the *New York* Section commenced on September 8th at Victor's Restaurant, with an enlightening and informative talk on "New Developments in Resistance Welding." The speaker of the evening was F. A. Bodenheim, sales manager—welders, for the Federal Machine and Welder Co., Warren, Ohio. In spite of the mid-summer temperature, this being the day after the long Labor Day week-end, a

BRAZING DISCUSSED BY HERRSCHAFT

D. E. Herrschaft discussing the use of brazing for high-temperature applications at the September 10th meeting of Long Island Section

Guest speaker Herrschaft receives the congratulations of Technical Chairman S. L. Messina, left, and Section Chairman K. W. Berry, right

group of 35 stalwart members were rewarded with an enthusiastic discussion of recent developments in resistance welding.

Mr. Bodenheim's talk centered around the application of resistance welding to high speed, fully automatic assembly lines. He explained that the majority of uses for resistance welding (spot, seam and flash welding) are in automotive and automotive-accessory fabrication. These applications account for about 60% of the total sales of equipment of this type. The second largest users are household-appliance manufacturers.

The speaker explained that the increased demand of consumers for products that better resist wear and corrosion at lower initial cost has caused most of the recent developments in resistance-welding procedures and equipment. This demand has brought about increased use of galvanized and vinyl-coated steel which must be fabricated by resistance welding. He then explained the methods that have been devised for welding these materials without damaging the appearance or long life of the coating. This need for better products has also raised the strength requirements of resistance welds so that a fewer number of high-quality welds are able to replace a great number of inconsistent welds. Timers and controls used in the welding equipment must, therefore, be more accurate and capable of repeated consistent performance.

Increasing the production rates as a means of reducing costs has caused a changeover in the basic principles of resistance-welding-machine manufacture. The resistance welding machine now becomes a machine tool that must fit into the plant assembly line and be capable of high-speed repetitive operation without impairing its versatility, so as to permit product-model changes from year to year. This trend has led to the adoption of fully mechanical operation of the machine's functions so that there is absolute synchronization of these functions regardless of the speed of operation. Previous use of separate timers and delay circuits for each function is too slow and much too difficult to synchronize with present-day high-speed production lines.

High repetition rates necessitated the use of improved control elements in resistance-welding machines to reduce maintenance and downtime to a minimum. Relays, controls and switches with almost infinite operation life are essential for trouble-free equipment in modern assembly lines. Mr Bodenheim illustrated these new developments with a film which showed in detail the operation of two mechanically synchronized high-production resistance-welding assembly lines.

The members took good advantage of the opportunity to fire questions at Mr. Bodenheim following his presentation.

SPEAKS ON ALLOY STEELS

Kenneth R. Notvest shown during his talk on welding of alloy steels at the September 8th meeting of Portland Section

POSITIONERS

Wellsville—The 1959–60 series of dinner meetings of the *Olean-Bradford* Section was inaugurated with the first meeting being held on September 15th at the Fassett Hotel in Wellsville. An excellent dinner put the 31 members and invited guests at ease for the meeting which followed. All three of the student members for 1959–60, one each from Bradford, Pa., Olean, N. Y., and Wellsville, N. Y., were present and were introduced to those present.

Robert P. Gehring, sales manager for the Cayuga Machine and Fabricating Co., Inc., was presented as the evening speaker by Section Chairman David Peterson. Mr. Gehring gave several important pointers on what to look for when buying positioning equipment. He illustrated his talk on special and standard-type positioners with an excellent set of slides. A question-and-answer period cleared up the questions brought up by the group.

Ohio

PLANT TOUR

Chillicothe—On September 11th, sixty members of the *Columbus*

PIN FOR PAST CHAIRMAN

Retiring Section Chairman C. J. Jensen, right, was presented with Past Chairman's pin by incoming chairman L. R. Constantine at May 9th meeting of Lehigh Valley Section

Section made a tour of the Chillicothe Division of the Meade Corp., manufacturers of paper and paper products. Dinner at Fox Farm preceded the tour.

ELECTRODE FUNDAMENTALS

Youngstown—An enthusiastic turnout of 95 members and guests attended the first session of the 1959–60 season of the *Mahoning Valley* Section on September 17th at Victoria Restaurant.

This year's meetings have been moved from Warren, Ohio, to Youngstown, Ohio, in hopes of obtaining increased attendance and interest with a consequent enlargement of membership. As a result of this meeting, it appears that the move has been well received and will be advantageous to all members and interested personnel in the area.

After a fine steak dinner and coffee-hour movie on "Helping the Taxpayer," a very excellent talk on "Fundamentals of Electrodes" was given by Joseph Caprarola, head of the Welding Engineering Department of Arcrods Corp. in Sparrows Point, Md. Mr. Caprarola's talk was supplemented by slides and was well received.

This discussion on electrodes covered mainly the basic aspects of welding electrodes, their classification and numbering system, coating and metal constituents and uses. Due to the shortage of time only mild-steel rods were covered. The AWS specifications on electrodes were discussed in detail.

The reasons for metal powder in iron-powder electrodes were given, along with the difference between contact and conventional electrodes. Low-hydrogen electrodes were then covered by the speaker, including the source of hydrogen during welding, why hydrogen produces troublesome welds and how hydrogen is removed from the low-hydrogen electrodes.

WELDING POSITIONERS

Bucyrus—The first meeting of the 1959–60 season of the *North Central Ohio* Section was held at the American Legion Home on Thursday, September 3rd.

An excellent dinner was served by the Women's Auxiliary of the Legion.

Speaker of the evening was Jack Jarms of the Harnischfeger Corp., who presented a very interesting and educational talk, accompanied by slides, on "Increased Efficiency Through the Use of Welding Positioners."

A very enjoyable evening was climaxed by the showing of a movie entitled "High Lights of 1968" of the Cleveland Browns Football Club.

Oklahoma

TRAINING COURSE

Oklahoma City—Forty-four members and guests of the *Oklahoma City* Section met on September 9th at Swyden's Restaurant. Cliff K. Bainum of Oklahoma State University, Stillwater, spoke on the training of young men in the field of metals technology. Mr. Bainum presented the required curriculum for a student in the Metals Technology School at Oklahoma State. The discussion also covered the technician's place in the welding industry as compared to the welding operator and the engineer.

Oregon

WELDING ALLOY STEELS

Portland—Twenty-eight members of the *Portland* Section were present at the first fall meeting

HI-AMP

ELECTRODE HOLDERS

CABLE ATTACHMENTS

GROUND CLAMPS

Offers

T.P.C.*

* THREADED POWER CONNECTION

Excessive heat in a welding circuit is oftentimes caused by a resistance build-up at some point in the welding circuit due to connections being loose or oxidization setting up in a mechanical type of terminal connection.

Shown in the above "cut-a-way" picture of an Electrode Holder is the new HI-AMP, T.P.C. type of connection that can be adapted to ground clamps and quick disconnect plugs as well as to electrode holders.

T.P.C. means a Threaded Power Connection using the pressure of threads on a sleeve to drive the ends of any welding cable down into the depth of a cable socket, then locked into place with threaded plugs. An excellent electrical connection as well as providing direct contact with the welding cable to the accessory so that maximum heat is conducted into the heat-absorbing cable.

ASK YOUR WELDING SUPPLY HOUSE FOR FURTHER INFORMATION

354 W. ADAMS ST. LENCO, INC. JACKSON, MO.

For details, circle No. 13 on Reader Information Card

held on September 8th at the New Heathman Hotel.

Chairman George Siegner called the meeting to order promplty after the members enjoyed a fine steak dinner. After a short business meeting, Vice-Chairman Harry Swan showed a short color movie entitled "Smoke Jumpers" sponsored by the Federal Division of Forestry.

Guest speaker for the evening was Kenneth R. Notvest recently appointed Welding Engineer for Willamette Iron & Steel Co. Mr. Notvest presented a very fine paper encompassing the problems encountered in the welding of medium-alloy chrome-alloy steels and pointed out that the key to sound ductile welds lies in proper thermal treatment throughout the welding cycle and reduction of carbon, hydrogen and oxygen from the melt.

This was a very fine presentation by Mr. Notvest.

Pennsylvania

LADIES' NIGHT

Bethlehem—On May 9th the *Lehigh Valley* Section had its Annual Ladies' Night at the Hotel Bethlehem with 114 members and guests present. Following cocktails and a buffet supper, there was a short ceremony installing the new officers who are L. R. Constantine, chairman; L. J. McGeady, vice-chairman; John Quigg, treasurer. Dancing and entertainment followed.

PLANT TOUR

Allentown—On April 13th the *Lehigh Valley* Section toured the plant of Air Products, Inc., at Trexlertown, Pa. Eighty members and guests were on the tour which included a demonstration of the effects of liquid oxygen and nitrogen on metals and various other materials. The operations necessary to manufacture air-reduction equipment were shown. The various welding processes used to weld the many types of metals were viewed with interest.

WELDING COURSE

Philadelphia—The evening college courses sponsored by the *Philadelphia* Section got under way for another season on September 15th. Educational Chairman Charles Dooley, welding engineer at Sun Shipbuilding and Drydock, is in charge of this activity.

These courses are of special interest to technicians, shop fore-

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men, shop supervisors, design draftsmen, engineers and practically everyone related to the fast growing and vastly important welding industry.

The courses offered are: Principles of Welding and Engineering, Parts I, II, III, covering welding processes, welding design, codes and specifications and inspection; also, elements of welding metallurgy, covering effects of heat on metal, ferrous and nonferrous; uses of rod coating and flux.

ALUMINUM WELDING

York—The *York-Central Pennsylvania* Section met on September 15th at the Viking Club for dinner and to hear a talk by Ivan A. MacArthur, Metal Research Laboratories, Olin Mathieson Chemical Corp. of New Haven, Conn. Mr. MacArthur's presentation was given by "command performance"—a return engagement by popular request. Questions were inspired to such an extent that a meeting scheduled for approximately one hour extended to almost two hours.

Advantages and disadvantages of the various welding processes used for joining aluminum were discussed. Selection of the proper grade of aluminum for a particular application was discussed in a general manner.

Several members of the Philadelphia Section who were especially interested in Mr. McArthur's subject were guests at this meeting.

Rhode Island

WELDING ELECTRODES

Providence — The *Providence* Section held their first dinner meeting of the 1959–60 season at the Johnson's Hummocks. There were approximately forty members and guests in attendance.

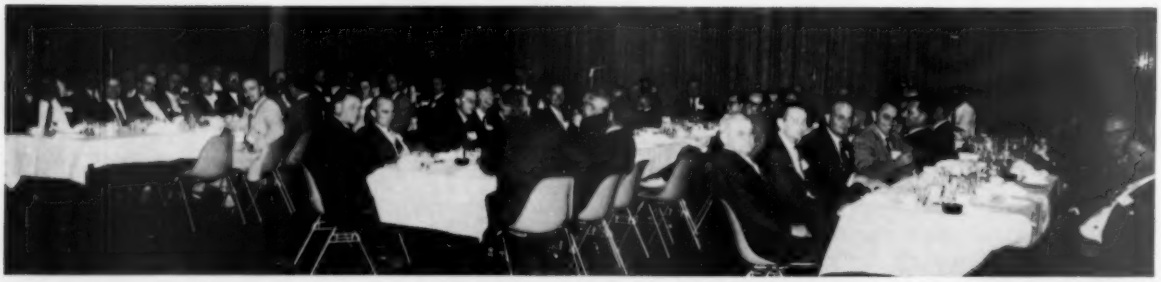
The Providence Section was fortunate in having as its speaker D. C. Smith, chief metallurgist of the Harnischfeger Corp. The subject of the talk was "Properties and Applications of Low-Hydrogen Iron-Powder Electrodes."

Dr. Smith indicated that the sale of manual welding electrodes was still increasing at an impressive rate. He reviewed the history of manual arc-welding electrodes and discussed the various functions of the covering.

A variety of interesting slides were shown and discussed covering the following: modern trends of coating ultra-high strength electrodes; major constituents in the organic, titania, iron oxide and basic low-hydrogen type of coating; comparison of deposition rates of E-6024, E6014, E6012, E6020 and E6027 electrodes. Also, E7016, E7018 and E7028 electrodes. Vee-notch Charpy-impact transition curve for three types and grades of mild-steel low-hydrogen weld metal; also vee-notch Charpy-impact transition curve of the E11016 and E11018 electrode weld-metal type in the "as-welded" condition. Effect of tempering on the tensile strength and elongation of 4130, 4140 and 4340 all-weld metal. Effect of tempering on the transverse-tensile strength, elongation and impact strength of BA105 weld metal used with 4340 base metal and effect of tempering on the vee-notch Charpy-impact of 4140, 4340 and Type 502 weld metals.

HOUSTON SECTION ADDRESSED BY GALTON ON WELDING POSITIONERS

Pictured at the September 16th meeting of Houston Section are, left to right, Program Director Don Middlehurst, Guest Speaker Paul Galton, Section Chairman M.C. Avis, and Director H. F. Crick



Part of the large crowd in attendance at the meeting to hear Mr. Galton speak on "Positioned Welding—A Step Toward Automation"

Texas

WELDING POSITIONERS

Houston—Eighty-nine members and guests of the *Houston* Section were present on September 16th at the Houston Engineering and Scientific Society for dinner and meeting.

Paul Galton, manager of sales for the Plainfield Division, Worthington Corp., Plainfield, N. J., was the speaker. He gave a very interesting 75-min talk on "Positioned Welding—A Step Toward Automation."

Prior to the technical meeting, a film furnished by Humble Oil & Refining, "Highlights of Southwest Football 1958 Season" was enjoyed by all.

SABINE DIVISION MEETS IN BEAUMONT

Caught in pleasant conversation at Houston-Sabine Division meeting on September 17th are E. H. Smith, Publicity Chairman, R. N. Rayfield, Division Chairman, Speaker Paul Galton and Houston Section Chairman D. Middlehurst

Here Mr. Galton is shown while addressing those present on the subject of positioning equipment as used in the welding industry

Peoria Section Sponsors Symposium

The Peoria Section of the AMERICAN WELDING SOCIETY, plans to present its First Annual Welding Symposium on Saturday, December 5th at Bradley University in Peoria. The technical speakers for the afternoon will be Omer Blodgett, design consultant at the Lincoln Electric Co., who will lead the discussion on "Design for Welding," Anthony Pandjiris, president of the Pandjiris Weldment Co. of St. Louis, will discuss "New Ideas in Machine Tools for Welding" and Helmut Thielsch, metallurgical engineer at the Grinnell Co. of Providence, R. I., will speak on "The Science of Welding Inspection."

Following the technical discussions, the event will be formally dedicated to Elmer Isgren, executive vice president in charge of manufacturing at the LeTourneau-Westinghouse Corp. in Peoria, who for many years has vigorously promoted the art and science of welding in this area.

The evening will terminate with a talk by Fred Plummer, National Secretary of the AMERICAN WELDING SOCIETY, who will discuss "Activities of the American Welding Society."

The registration fee for the event will be $5.00, which will include the cost of the evening meal.

POSITIONING FOR WELDING

Beaumont—Sixty members and guests of the *Sabine* Division met on Thursday, September 17th at Monte Leon Hall in Beaumont. Paul Galton, manager of sales for Worthington Corp., Plainfield Division, Plainfield, N. J., spoke on various positioners and manipulators manufactured and the development and engineering that go into these pieces of equipment. A history of positioning equipment was given and slides showing the latest uses of same.

PANEL DISCUSSION

San Antonio—The *San Antonio* Section met on September 8th at Captain Jim's Cafe for dinner and meeting. With W. B. Hamilton, Jr., as moderator, a panel discussion was held on problems which occur frequently in the welding profession. It is felt that much benefit is derived from these question-and-answer forums. The speakers were E. E. Wagner, J. R. Wallace, H. F. Burkhart and W. H. Wood. Their subjects were: Problems in Welding T-1 Steel; Welding Fatigue; Methods of Welding Cast Iron and Causes of Undercut.

Madison Section Collaborates with University of Wisconsin

A two-day Welding Institute featuring the presentation of eight major topics in stainless-steel fabrication followed by an award of certificates is planned for Thursday and Friday, November 19th–20th, by the University of Wisconsin Extension Division, Dept. of Engineering and the Madison Section of AWS.

Designed to aid welding supervisors and engineers in this fast-growing field, the Institute will offer qualified speakers from nationally known, leading industries who will present the subjects according to the tentative program:

Thursday, November 19th

9:00 A.M.	Fabrication of Stainless-Steel Tanks, Piping, Dryers, etc.
10:30 A.M.	Welding Stainless Steel to Low-Alloy Steel
1:00 P.M.	Proper Positioning and Fixturing of Parts
2:40 P.M.	Panel Discussion—Solving Stainless-Steel Welding Problems
6:30 P.M.	What's New in Welding Processes

Friday, November 20th

9:00 A.M.	Nondestructive Testing of Stainless-Steel Welds
10:30 A.M.	Cutting of Stainless Steels
1:00 P.M.	Panel Discussion—Comparison of Various Gases Used—Helium, Argon and CO_2
3:00 P.M.	Presentation of Certificates

During panel discussions the speakers will answer questions concerning welding problems.

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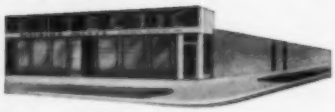

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B—Member
C—Associate Member
D—Student Member
E—Honorary Member
F—Life Members

TOTAL NATIONAL MEMBERSHIP

Sustaining Members	195
Members	6,184
Associate Members	5 597
Students	243
Honorary Members	11
Life Members	10
Total	12,246

ARIZONA

Spear, William D. (B)

BATON ROUGE

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Vaughan, V. H. (C)

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Jones, Richard D. (C)
Mondlick, Robert E. (C)

BRIDGEPORT

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Gavin, Robert Richard (C)
Hofmaier, Dennis J. (C)
Janns, Raymond E. (C)
Neil, Alfred Q. (C)
Peterson, Paul H. (C)

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Schaefer, Louis O. (B)

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Archer, Haworth A. (B)
Schwahl, Edward D. (C)
Wimer, Delbert E. (B)

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Elter, Robert E. (C)
Grofsorean, Emil (B)
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Johnson, Niel E. (B)
Smith, Emmons Edwin (B)

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MacLeod, Donald M. (C)

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Allen, James Loyd (B)
Taylor, Claude S. (B)

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Crawford, Champ E. (B)
Irvin, Walter L., Jr. (C)
McAvoy, Frank J. (B)
Willing, J. L. (B)

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Sackenheim, Joseph B. (C)

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Sutliff, Floyd Raymond (B)

J. A. K.

Bretto, Sam J. (C)
Brown, Harry L. (C)
Drake, Dale L. (C)
Fishbeck, John Paul (C)
Judy, Robert G. (C)
Lietzow, Keith A. (C)
Marek, Ben A. (B)
McCarter, Francis L. (C)
Pruitt, Bert (C)

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Ellis, Kenneth A. (B)
Hall, Ralph (B)
Hallmark, Robert F. (B)
Levin, Robert (B)
Marks, Alan H. (B)

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Stein, John P. (C)

MARYLAND

Hol, William A. (C)
Rolnick, Jerome M. (C)

MICHIANA

Spitzmesser, Ray Edwin (C)

MILWAUKEE

Lotz, Charles W. (B)
Morrissey, Robert (B)
Stoffers, Henry B. (C)
Strand, Reuben M. (C)

NASHVILLE

Barlow, George W. (D)
Beeman, Harold Eugene, Jr. (D)
Davis, Bill (B)
Dunbar, Robert H. (D)
Edwards, Joseph L. (C)
Fabri, Andy (C)
Ferrell, John V., Sr. (C)
Frost, A. W. (C)
Green, C. W. (C)
Justice, Richard F. (B)
Malone, Ollie Robert, Jr. (B)
Martin, John L. (D)
Meade, Charles R. (D)
Patterson, Jimmy S. (D)
Speer, Dorman Po (D)
Vickery, James E. (B)
Wheeler, Robert L. (D)
Whittaker, Daniel E. (D)

NEBRASKA

Utemark, Eugene (B)

NEW JERSEY

Dolan, William (C)
Flannery, John W. (B)
Gurry, Robert W. (B)
O'Hara, Thomas J. (C)
Smith, Edwin B. (B)

NEW YORK

Lenhard, Robert E. (C)
Stender, Robert C. (C)

NIAGARA FRONTIER

Carson, John M., Sr. (B)

NORTH CENTRAL OHIO

Cunningham, Thomas J. (C)

NORTHWEST

Marston, Donald F. (C)
May, Charles H. (B)

NORTHWESTERN PA.

Hemme, Vern (C)

OKLAHOMA CITY

Allen, Loyd (C)
Martin, T. T. (C)

OLEAN-BRADFORD

Huff, George R. (B)
McAdams, Robert W. (B)

PEORIA

Robinson, Robert L. (C)

PHILADELPHIA

Donnelly, John J. (B)
McArdle, Edward H., Jr. (C)
Piland, Julius A. (C)
Smith, Kenneth N. (B)

PITTSBURGH

Mapstone, Dale A. (C)
Selwyn, Myron A. (C)

PROVIDENCE

Thielsch, Helmut (A)

PUGET SOUND

Lemon, Lloyd C. (B)

ST. LOUIS

Sauder, Gerald K. (B)

SAN ANTONIO

Yates, Homer T. (B)

SAN FRANCISCO

Cummings, Kelton V. (B)

SANGAMON VALLEY

Smith, Le Roy H. (C)
Wysocki, A. J. (B)

SANTA CLARA VALLEY

Mazzone, Barney Irving (C)

STARK CENTRAL

Wilt, Fred C. (B)

SUSQUEHANNA VALLEY

Whelley, John G. (C)

TULSA

Brown, Herbert J. (B)

WASHINGTON, D. C.

Crowley, Lt. John D. (B)

WICHITA

Brown, Virgil S. (C)
Hodges, Robert K. (C)
Roberts, William R. (C)

YORK-CENTRAL PA.

Williams, E. L. (B)

MEMBERS NOT IN SECTIONS

Klein, Harry (C)
McGarry, John (B)
Vogel, Erwin Paul (B)
Werthwein, Carl (B)

Members Reclassified During September

BIRMINGHAM

McMahon, William R. (C to B)

CLEVELAND

Fabish, Joe P. (D to C)

DETROIT

Piggott, Harold E. (B to A)
Powers, William J. (C to B)

LOS ANGELES

Herold, David W. (C to B)

PEORIA

Bogart, Eldred (C to B)

PHILADELPHIA

Campbell, Hallock C. (C to B)
McKearney, T. A. (C to B)

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2,841,691—Negative Forge Timing for Resistance Welders—Stuart C. Rockafellow, Farmington, Mich.

Rockafellow's patent is on a process for electric resistance welding wherein the process includes squeezing the welding electrodes together until they exert a substantially constant pressure on the work, passing a welding current through the electrodes and performing a forging operation by changing the pressure exerted on and by the welding electrodes during the passage of the welding current. The patent particularly is directed toward an improvement to make the steps referred to a predetermined length and to perform such steps in timed relationship to each other as the result of separate timing operations.

2,842,656—Inert Gas-Arc Welding Apparatus and a Shield and an Electrode Holding Chuck for Use in Said Apparatus—George J. Neuvirth, Lodi, N. J.

The patented inert gas-arc welding device includes a cylindrically shaped electrode holding chuck and a reversible electrode carried by the chuck. A shield is provided for the chuck and electrode, and a hand element engages with such a shield and positions the electrode holding chuck for operative action.

Abstracts of Current PATENTS

prepared by Vern L. Oldham

Printed copies of patents
may be obtained for 25¢ from the
Commissioner of Patents, Washington, D.C.

2,842,835—Articles of Titanium Alloys—Harold Ernest Gresham, Little Eaton, and Dougas Wilson Hall, Tynemouth, England, assignors to Rolls-Royce Limited, Derby, England.

The present patent on making articles from titanium alloys includes a method comprising forming the articles in the parts to be welded together so that the places where the welds are to be made are greater in cross section than the parts of the material adjacent thereto which are too thin for welding action. The junction between the parts on one side of the article is grooved for receipt of filler material and the parts are welded together using titanium alloy filler. The other side of the article is similarly grooved and welded with filler material. Lastly, the junction so made is forged down so that its thickness substantially equals that of the material adjacent thereto and then the article is annealed to complete it.

2,842,840—Method of Fabricating Glass-Coated Metallic Articles—Edwin C. Ploetz, Kankakee, Ill., assignor to A. O. Smith Corp., Milwaukee, Wis., a corportion of New York.

Ploetz' patent is on the fabrication of a glass-lined tank structure from preformed steel members. A glass composition is applied to the interior surfaces of the preformed steel members and a coating of paraffin compound is applied adjacent the ends of the members to be joined together. Then the steel members are welded together along contiguous surfaces and the welded tank so formed is fired at a temperature of approximately 1600° F to fuse the glass composition to the tank interior. Such a composition flows into and seals the welded joints between the members and the elevated temperature stress relieves the welded tank structure.

2,843,478—High-Temperature Brazing Alloy for Joining Fe-Cr-Al Materials and Austenitic and Ferritic Stainless Steels—Ronald R. Cost, Cincinnati, Ohio, assignor to the United States of America as represented by the United States Atomic Energy Commission.

Cost's patented brazing alloy is made from 19 to 20% by weight chromium, 5 to 6% aluminum, 9.5 to 10.5% silicon, 1.5 to 5% phosphorus and the balance is iron.

2,843,722—Apparatus and System for Producing Honeycomb Core—Milton G. Wegeforth, San Diego, Calif., assignor to Solar Aircraft Co., San Diego, Calif., a corportion of California.

This patent is on apparatus to produce a honeycomb structure from transversely corrugated ribbon. The apparatus has means to assemble such ribbon on the form of a cellular honeycomb of adjacently disposed oppositely corrugated ribbon sections. Other means are operative to bond the nodes of the adjacent ribbon sections together, when so assembled, to form the unitary honeycomb.

2,843,723—Welding Apparatus—Thayer R. Brunson, Denver, Colo., assignor to Rocky Mountain Metal Products Co., Denver, Colo., a corporation of Colorado.

Brunson's patent is on means for moving electrodes into and out of engagement where the electrodes are carried by a fixed post and a movable post and are normally held in engagement by pressure means. The electrode moving means includes two spaced hand rest levers and a rocker arm connecting the hand rest levers with one another and with the movable post. This arm effects separation of the electrodes upon both joint and independent movement of the hand rest levers.

2,843,724—Electric-Welding Method—Albert M. DeGaeta, Brooklyn, N. Y., and Frank W. Klimm, Maywood, N. J.

An electric resistance butt-welding method is shown by the present patent. Two members to be welded are provided with faces that are substantially parallel but with projecting portions proving initial point contact when the members are brought together, and such members are connected through a low impedance external circuit to opposite sides of a charged condenser. The members are then moved together under controlled force action and the electrical resistance between the members on initial contact is greater than that of the external circuit and a decreasing contact resistance is set up as the members continue to move toward one another. The instantaneous discharge of the condenser through the contact resistance between the members produces concentrated localized heat to soften only the faces of the members and an impact is provided at the end of the movement sufficient to produce a weld between the softened faces of the metal members.

2,843,725—Box Section and Method of Making—Neil B. Granberg, Wauwatosa, Wis., assignor to A. O. Smith Corp., Milwaukee, Wis., a corporation of New York.

The present patent is on a method of forming a box section from a pair of channel members, each having longitudinally extending flanges joined by a web. First a plurality of depressions are formed in the flanges of one channel member to provide a surface facing in the same direction as the longitudinal edge of the flange on which the depression is made and which depression is spaced transversely from the body of the flange on which the depression is made. Next the second channel member has its flanges brought into contact with the surfaces of the depressions on the first channel member. A resistance heating current is passed between the edges of the flanges of the second channel member and the depression surfaces and the flanges and depression surfaces in the channels are forced together to form a welded box member of high strength.

2,843,726—Method for the Fabrication of Very Small Thermocouples—Earl F. Kiernan, San Diego, Calif.

Kiernan's patent is on a specialized method of fabricating thermocouples of fine wire. The method includes passing a welding current through at least the ends of a pair of twisted thermocouple leads in series with a mercury bath that contacts such wire ends and has an oil surface seal.

2,843,727—Method and Apparatus for Gas-Shielded Localized Welding—William G. Benz, Jr., Rutherford, Jesse S. Sohn, Succasunna, and Richard B. Steele, New Providence, N. J., assignors to Air Reduction Co., Inc., New York, N. Y., a corporation of New York.

In this gas-sheided arc stud welding method, a gas nozzle is positioned in operative relation to a localized region on the workpiece to be welded, and a shielding gas envelope is discharged from the nozzle to exclude air from such localized region. A welding arc is established between the workpiece and a consumable wire electrode and the electrode is fed to the workpiece at a rate substantially equal to the burn-off rate of the wire. Next the arc is extinguished and the feed of the electrode is continued so as to drive the electrode into the molten weld metal after which electrode feed is stopped. The gas envelope is maintained about the molten weld metal until it solidifies after which the electrode is cut off at a desired length.

2,898,440—Forming and Welding Metal Tubes and Sheathes—Wallace C. Rudd, Larchmont, Hugh J. Cameron, New Rochelle, and David G. Osterer, Harrison, N. Y., assignors to Magnetic Heating Corp., New Rochelle, N. Y., a corporation of New York.

This patent relates to apparatus for making metal tubing from a metal blank previously formed into a generally tubular configuration but having a longitudinal V-shaped gap between the edges of the blank. A pair of contacts are mounted to engage the surfaces of the metal blank along opposite sides of the gap therein shortly in advance of the weld point and a source of current of a frequency in the order of about 100,000 cps connect to the contacts. A countinuing element of magnetic material is positioned inside the blank to extend longitudinally thereof and other means concurrently advance the blank and the element with relation to the contacts and past the weld point while bringing the edges of the blank together. Successive portions of the element of magnetic material act to increase the reactance of the paths of current flow between the contacts in directions around the blank and to thereby increase the current flow along the edges of the V-shaped gap to and from the weld point.

2,898,443—Tracing Weld Metal—George E. Havemeyer, Guilford, Conn., assignor to Gregory Industries, Inc., Detroit, Mich., a corporation of Michigan.

Havemeyer's patent is on a method of forging using a minimum of forging stock. In the method, a grip stud is welded to a metal billet and an alloying material is introduced into the weld, which alloying material has a contrasting chemical etch reaction when alloyed in the billet as compared to the billet stock. Thereafter the billet is forged and the produced member has the flash trimmed therefrom. Lastly, the forged material is etched to determine the extent and location of the contrasting etch in the finished forged blank to determine whether the alloying material has been fully removed.

For details, circle No. 17 on Reader Information Card →

World's champion corn picker welded with M&T Murex
ELECTRODES

In the past eight years, five championships have been won by farmers using the New Idea corn picker. It is also the world's biggest selling brand. For the kind of welds that contribute to championship performance year after year, the New Idea Division of Avco Distributing Corporation depends on M&T Murex electrodes—products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

MUREX
PRODUCTS FOR BETTER WELDING

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For details, circle No. 18 on Reader Information Card →

World's thirstiest flood pumps welded with M&T Murex ELECTRODES

Some of the biggest pumps in the world are controlling flood damage in Florida's Lake Okeechobee area. With intake pipes 12 feet in diameter, they suck up swimming pool sized gulps of flood waters every second, spew it out into a series of reservoirs. Though not yet complete, the system has already prevented an estimated $44-million damage. The thirteen Fairbanks-Morse pumps in use were welded with M&T Murex electrodes—products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

MUREX
PRODUCTS FOR BETTER WELDING

NEWS of the industry

Resume Welding Training

After several years omission from New Jersey High School Industrial Arts classes, welding training is being resumed in 21 high schools in the state.

This past summer, the Industrial Arts Department of Trenton State Teachers College, under the direction of Robert M. Worthington, chairman of the Industrial Arts Department, conducted a general welding workshop for industrial arts teachers from 21 schools. Each "pupil" spent eight hours daily studying the latest theories, methods and practices in electric-arc and oxyacetylene welding. Each also had to construct one project which could be made by shop students at his school back home. Welding instructors for the course included Robert Bercaw AWS of Hobart Brothers Co., Robert Gihand of the Linde Co. and Kevin Sheppard of R. S. McCracken and Sons, Hobart welding distributor in Trenton.

Dr. Worthington said the high interest in the class indicates a strong movement to place welding practice back in High School Industrial Arts shops in the state. At the close of the workshop, each of the 21 teachers received a certification for teaching welding in their respective schools. Since teachers are not permitted to teach welding in New Jersey unless they have this teaching certificate, Trenton State Teachers College will conduct a similar welding workshop every summer and they hope to have, in a few years, all of the Industrial Arts Teachers in the state supplied with welding teaching certificates. In addition, welding is now included in the curriculum for all Industrial Arts Students at Trenton State Teachers College and their 1959–60 catalog lists welding for the first time.

A typical workshop project

Industrial-arts teachers from 21 New Jersey high schools look on as Robert Bercaw of Hobart Bros. Co. demonstrates vertical welding

Farm Welding Contest

Award-winning entries in this year's annual welding competition sponsored by the James F. Lincoln Arc Welding Foundation of Cleveland, Ohio, for farm boys ranged all the way from loading chutes and hay elevators to a raisin shaker (California). All entries were shop projects constructed by the boys.

National honors were shared by 105 young farmers from 26 states. These boys, and the schools where they study shop mechanics as part of

COMING EVENTS

A Calendar of Welding Activity

AWS National Meetings

41st Annual Meeting and Eighth Welding Show:
April 25–29, 1960. Biltmore Hotel, Los Angeles, Calif.

1960 National Fall Meeting. September 26–29. Penn Sheraton Hotel, Pittsburgh, Pa.

ASM

November 2–6, 1959. 41st National Metal Exposition and Congress. International Amphitheatre, Chicago, Ill.

NWSA

November 30–December 1. Southeastern Zone Meeting, Atlanta, Ga.

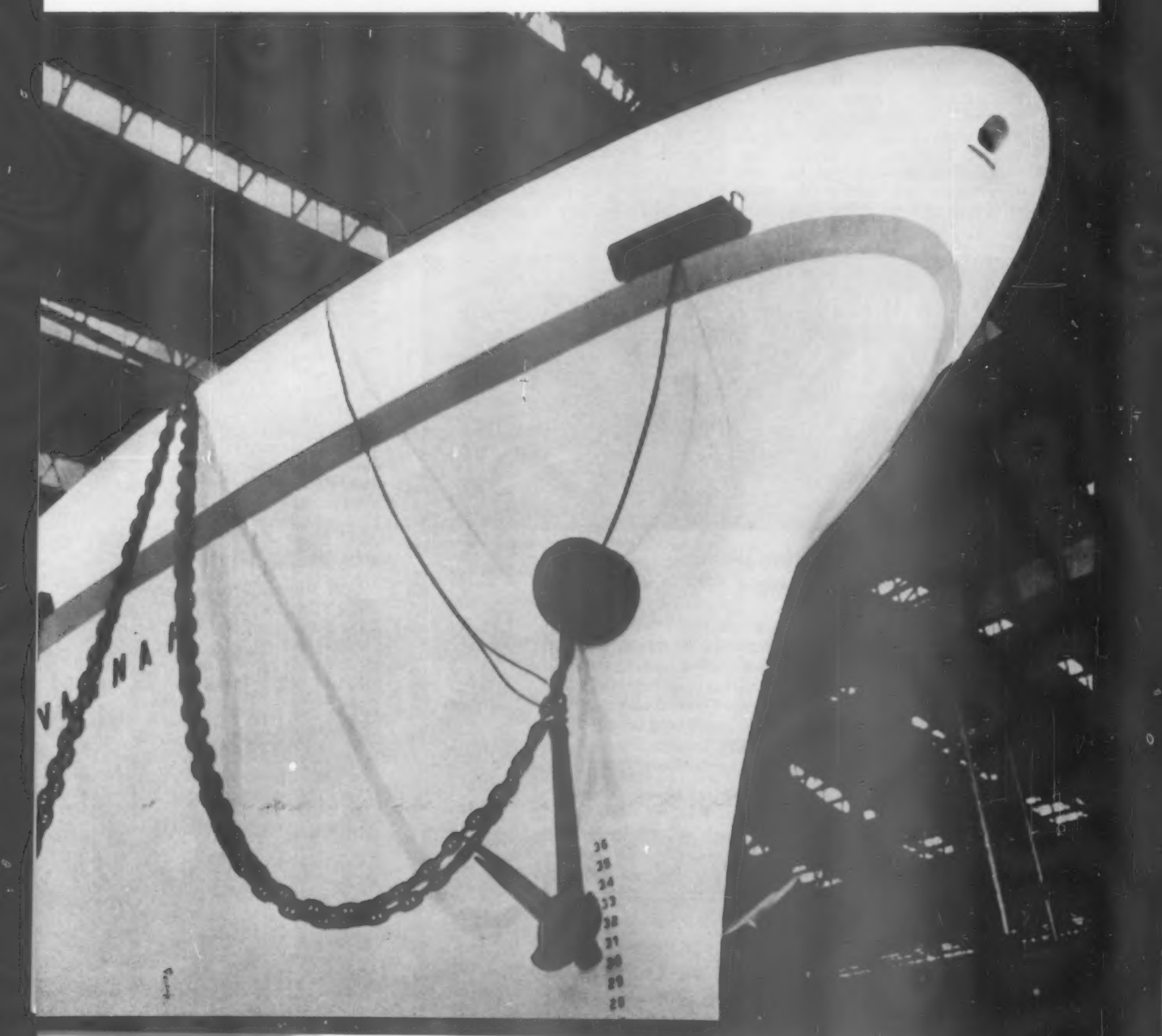
December 3–4. Southwestern Zone Meeting, Hotel Texas, Fort Worth, Texas.

For details, circle No. 19 on Reader Information Card →

World's first atomic cargo ship relies on M&T Murex ELECTRODES

The N.S. Savannah, world's first nuclear-powered merchant vessel, is designed to prove the feasibility of "Atoms for Peace." Scheduled for initial service in the summer of 1960, she will cruise at 21 knots with a cargo of 10,000 tons, a 110-man crew and 60 passengers. In constructing the safety container for the atomic reactor, heart of the vessel's power system, the New York Shipbuilding Corp. relied upon Murex electrodes—products of METAL & THERMIT CORPORATION, General Offices: Rahway, New Jersey.

MUREX
PRODUCTS FOR BETTER WELDING



agricultural courses, received a total of $7000.

Gregg Hollinger of Paul, Idaho, received the top national award of $600 with his branding and dehorning squeeze chute.

Second award of $400 went to Michael R. Redmond of Medford, Ore., for his tilt-bed implement trailer. Third awards of $200 each were won by Tracy W. Beale of Pomeroy, Wash., with his cattle squeeze chute, and James Horn of McPherson, Kan., with his adjustable and portable livestock loading chute.

ACRO WELDER MFG. CO.
MILWAUKEE
WELDING ENGINEERS
MACHINERY BUILDERS
ESTABLISHED 1936
For details, circle No. 20 on Reader Information Card

Ampco Weldrod Distributors Named

The appointment of several new stocking distributors of Ampco bronze Weldrod products has been announced by Ampco Metal, Inc., Milwaukee, Wis.

The new distributors are: Acme Welding Supply Co., Kansas City, Mo.; Aviation Service Supply Co., Denver, Colo.; Essex Welding Equipment Co., Newark, N. J.; Welders Supply, Inc., Dallas, Tex.

Effective immediately, the new distributors will handle the complete line of Ampco-Trode, Ampco-Trode "AC" and Phos-Trode electrodes, filler rod and spooled wire in addition to Ampco-Brāz gas welding and brazing rods.

NCG Moves Office to New Location

The Buffalo district office and warehouse of the National Cylinder Gas Division of Chemetron Corp. have been moved to 396 Grand Island Boulevard, Tonawanda.

The new location offers expanded area for sales, offices and storage. NCG produces and markets industrial and medical gases, welding and cutting equipment, a line of inhalation therapy equipment and other medical apparatus.

Nondestructive Testing Training Course

The Magnaflux Corp., 7300 W. Lawrence Ave., Chicago 31, Ill.,

offers week-long courses in nondestructive testing for eight men at a time for a fee of $100 at their Chicago plant.

Robinson-High Vacuum Merger

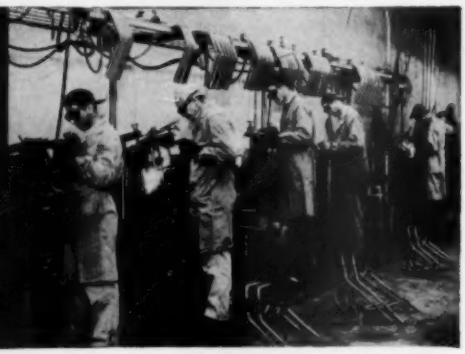
C. S. Robinson, president of Robinson Technical Products, Inc., Teterboro, N. J., and Joseph B. Merrill, president of High Vacuum Equipment Corp., Hingham, Mass., have announced the merger of the two companies.

High Vacuum Equipment Corp. will be operated as a wholly owned subsidiary of Robinson Technical Products, Inc., and will retain its present management.

New Airco Outlet

Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y., has opened a new branch in Cleveland. Known as East Side Welding

TOP QUALITY FLUXES
made by All-State for
WELDING
BRAZING
SOLDERING



Production line brazing with automatic fluxing system. Information on All-State JET FLUX® on request.

POWDERED flux is micro-ground; PASTE flux is homogenized

At ALL-STATE each flux is manufactured to rigid specifications, tailored for best results with specific alloys. For example, ALL-STATE's S-200 silver brazing flux affords complete protection to heated base metal to 1800° F., insuring excellent capillary action and easy flowing of silver alloy. Melts at 600° F. Equal care is built into other fluxes made by ALL-STATE to assure oxide-free bonding of all metals at low temperatures.

Ask for free copy of 58-page Instruction Manual. Write for information on fluxes custom coated on your own rods.

All-State
Distributor-Stocked, convenient to buy, Economical to use.
ALL-STATE WELDING ALLOYS CO., INC., White Plains, N. Y.
Call WHite Plains 8-4646 or write for nearest distributor.

For details, circle No. 21 on Reader Information Card

Supply, the outlet will market industrial gases, arc and gas welding and cutting equipment to customers throughout the east side of Cleveland. Vince Horrigan will manage the facility. He previously held the position of assistant manager of sales at Air Reduction's district office in Cleveland.

Pressure-pipe Welding Course

A special training course on the welding of pressure piping is now being offered by the Hobart Welding School, Troy, Ohio.

The course is open to trained and experienced welding operators only and features the "uphill" technique of starting at the bottom of the joint and welding to the top. Upon completion of the course, the operator should be capable of passing the Performance Qualification of Section IX, ASME Boiler and Pressure Vessel Code. The average length of the course is four weeks.

Illinois State Fair Cutting Contest

Over 300 persons competed in a cutting contest held at the Illinois State Fair in Springfield, Ill., August 14th to 22nd. The contest, sponsored by Ill-Mo Welding Products Co., of Jacksonville, Ill., was won by Lamar Loucks of Hillsboro, Ill., and Ray Bethard of Ray's Welding and Machine Works, Taylorville, Ill.

Contestants cut through a 4-in. length of $^3/_8$-in. mild steel, using a hand-cutting torch, and were timed by stopwatch. Fastest time for the cut was 7.2 sec. Winners received oxy-acetylene welding equipment.

The Ill-Mo exhibit was viewed by over 10,000 persons and has been a regular feature at the fair for over 12 years. Live displays of electric and oxyacetylene welding, spot welding and hardfacing of farm equipment provided interesting watching for the Fair visitors in the large circus-like tent.

Manufacturers cooperating in the exhibit were the Linde Co., Harnischfeger Corp., Stoody Co., Miller Electric Manufacturing Co. and Aladdin Rod and Flux Manufacturing Co.

Nuclear Reactors

One of eight welded pressure vessels, this pressurized, water-type reactor will be installed in the world's first atom-powered aircraft carrier, the *Enterprise*. The vessel flange is 18 in. thick and 137 in. OD. The 7-in. thick manganese-molybdenum shell was cold formed. Internal stainless-steel cladding was performed by an automatic weld-cladding process and final machining was temperature controlled and employed optical measuring devices. The 100-ton reactor vessel and the 50-ton closure head was shipped from Foster-Wheeler's Mountaintop, Pa., plant to Newport News, Va.

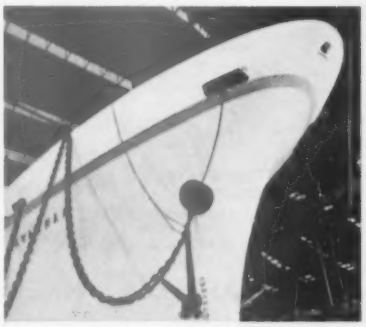
National-U.S. Radiator Buys Plant

National-U. S. Radiator Corp., Johnstown, Pa., has purchased Magnetic Powders, Inc., which operates a plant at Johnsonburg, Pa. The new acquisition was obtained from Radio Cores, Inc., Oak Lawn, Ill.

In addition to the production of special metal powders, it is planned to make a number of hydrogen-re-

Corn Picker

Flood Pumps



Nuclear Ship

...where you find companies that take great pride in the superiorities of their product, you'll generally also find great reliance on Murex welding electrodes.

Murex electrodes comprise one of the broadest lines of quality rods and wire. Choose from over 1000 types and sizes—mild steel and low alloy, stainless, hard surfacing, etc. Ask the M&T man or send for free literature. Also for information on M&T's complete line of welding machines.

M&T welding products

METAL & THERMIT CORPORATION
General Offices • Rahway, New Jersey
For details, circle No. 22 on Reader Information Card

Job Report Courtesy of
Alco Products, Inc., Schenectady, N. Y.

Nuclear pressure vessel stainless clad at low cost

USE ARCOS

STAINLESS WIRE and BONDED FLUX

This "barrel" is one of several that comprise a nuclear pressurizer to operate under highly corrosive conditions. To reduce costs, Alco Products forged the shell of ASME A-336, 2—4 inch thick manganese molybdenum steel and clad the inside with stainless. The illustration shows the second pass overlay which was made by submerged arc using Arcos Chromenar K-LC (Type 308) bare wire and Arcosite S4 flux. Lower cost, and high corrosion resistance with optimum physical properties were obtained. ARCOS CORPORATION, 1500 South 50th St., Philadelphia 43, Pa.

Bare Wire

Arcosite Flux

For details, circle No. 23 on Reader Information Card

duced iron and other powders at the Johnsonburg plant in the near future.

Canadian Home Study on Welding Aluminum

Along with other home-study courses offered by the Canadian Welding Bureau, there will be added in October a 22-lesson course on the welding of aluminum covering all the principal fusion-welding methods of joining aluminum including metal-arc, gas metal-arc, gas tungsten-arc, oxyacetylene, brazing and such special applications as gas metal-arc stud welding and arc cutting. Other lessons embrace such important subjects as the properties and weldability of aluminum and its alloys, quality control and supervision, design principles, safety, terms and symbols, comparison of processes.

Each lesson is accompanied with assigned problems which must be returned on time. Final examination will be conducted in June of each year and those successful will be issued the official diploma of the Bureau. Further details may be obtained from the Canadian Welding Bureau, 1393 Yonge St., Toronto, Ont., Canada.

Pyromet Co. Builds New Brazing Facilities

Construction began recently on Pyromet Co.'s $250,000 permanent production plant and offices at a San Carlos, Calif., site. Early in 1960, the staff will move into the new quarters which are located at Industrial Way and San Carlos Ave.

Pyromet performs brazing and heat-treating services for the aircraft, missile, nuclear energy and electronics industries.

The 22,000 square-feet facility will enable Pyromet to house its specially designed production equipment. Included are a new bell furnace with 6-ft diam working area for dry-hydrogen brazing and a new Pyromet-developed high-vacuum furnace. Additionally, there will be a modern metallurgical laboratory for the firm's growing research and development program.

Spooled Aluminum Wire

Production capacity for spooled aluminum wire is about to be tripled by All-State Welding Alloys Co., announces T. D. Nast, president.

The company is now in a position to spool, on 1- and 10-lb spools, every type of aluminum used for welding—#1100, #4043, #718, #5154,

#5554, #5356, #5183, #5556, etc. New spooling machines are being added to the home plant in White Plains and at the company's western plant in South Gate, Calif.

Next step in All-State's expansion program, says Mr. Nast, is the spooling of various grades of copper wire, such as deoxidized copper and silicon bronze. The company also plans to spool magnesium, stainless steel and mild steel wire.

Airco Completes Denver Plant

Announcement has been made by Air Reduction Sales Co., a division of Air Reduction Co., Inc., 150 E. 42nd St., New York 17, N. Y., of the completion of a new oxygen and nitrogen plant at Denver, Colo.

William O. Brown is in charge of all Airco operations at Denver. Leo C. Jones, formerly superintendent of the Airco oxygen plant at Hobbs, N. Mex., has been appointed superintendent of the new facility.

Safety Citation for NCG Plant

Employees of the Cicero, Ill. plant of the National Cylinder Gas Division of Chemetron Corp. have received a certificate of distinguished service in industrial accident prevention for their safety record of more than half a million man-hours worked without a lost-time accident in 1958.

The award was presented to Carl Fritch, Jr., manager of the NCG Cicero plant, by the American Fore Insurance Group.

Amperex Announces Promotions

Amperex Electronic Corp., Hicksville, Long Island, N. Y., has announced the establishment of two new executive positions and the promotions from within the organization to fill the posts.

John Messerschmitt has been promoted to the position of manager, power tubes and renewal sales.

Irwin Rudich has been promoted to manager, special purpose tubes and semiconductors.

Amperex is engaged in the research and development, manufacture and sales of electron tubes and semiconductors for Government, communications and industry.

WANT MORE DETAILS?
. . . . . .
USE
READER INFORMATION CARD

Job Report Courtesy of
Southwest Welding & Mfg. Division,
Yuba Consolida.ed Industries, Inc., Alhambra, Calif.

When strong welds are needed to resist impact at minus 320°F

WELD WITH ARCOS

STAINLESS ELECTRODES

This six-section spherical liquid oxygen container is made of Type 321 stainless steel. Walls 4½" thick were required to withstand 3000 psi pressure. To assure crack-free welds to meet ASME impact properties at −320°F, it was welded with Arcos Chromend 19/9Cb-LC electrodes with controlled ferrite. The first time—and every time you use Arcos electrodes—you get top performance, save time, and money. ARCOS CORPORATION, 1500 South 50th St., Philadelphia 43, Pa.

For details, circle No. 24 on Reader Information Card

PERSONNEL

Sherwood Retires; Hobart Names Buchanan

On Sept. 1, 1959, Richard L. Sherwood, AWS, who has been with Hobart Brothers Co. for the past 16 years and territorial manager for seven, announced his retirement. He will be succeeded by Robert K. Buchanan AWS, until recently eastern district manager with headquarters in Philadelphia. Mr. Buchanan, who will assign distributor territories, entered the welding industry in 1954 with Hobart Welder Sales & Services, Inc., in Philadelphia.

National Welding Equipment Advances Brown, Peacock

Richard K. Brown has been appointed vice-president and general manager of National Welding Equipment Co. as of Sept. 1, 1959. He has been actively engaged in the welding industry and in numerous phases of steel fabrication.

C. B. (Bart) Peacock will take over Mr. Brown's job as general sales manager of the company. Mr. Peacock was Mr. Brown's assistant in the capacity of assistant sales manager.

Ernest L. Mathy AWS, who has been in the welding industry for over 43 years, remains in the capacity of president and chairman of the Board, and will concern himself primarily with the company's finances, basic policies and advertising.

Berlin Named Sales Manager

Arthur Berlin has been named Eastern Division sales manager for the Sight Feed Generator Co., West Alexandria, Ohio. Mr. Berlin has had 20 years of experience in engineering and sales and will give technical assistance to Rexarc and Sight Feed users in the area. Mr. Berlin, formerly associated with Automation Industries, Inc., will devote his full time to the sales and service of Sight Feed products in the Eastern area. A company Division office has been established at 790 Broad St., Newark, N. J.

Smith Fills New Douglas Post

The Douglas Aircraft Co., Long Beach Division, has announced the promotion of C. B. Smith to the newly created position of chief of vendor product reliability assurance. This project is intended to pursue a program of vendor education, product performance testing, product improvement and supplier source selection.

Mr. Smith has had 18 years' experience in the materials and process engineering project where he was assistant chief. He is a member of the national board of directors of the AMERICAN WELDING SOCIETY, and is past-chairman of the Los Angeles Section of the SOCIETY. He has contributed numerous papers and participated in the symposiums of the AMERICAN WELDING SOCIETY and other engineering groups.

Richard K. Brown

C. B. Peacock

Arthur Berlin

Richard R. Sherwood

Robert K. Buchanan

C. B. Smith

Wade Appointed by Union Carbide

Sidney Wade has been appointed vice-president, distributor products of Linde Co., division of Union Carbide Corp., it has been announced by William B. Nicholson, division president.

Mr. Wade began his business career with Union Carbide's Oxweld Acetylene Co. in 1921. He joined Linde in 1929 when Oxweld was merged with the company. In 1956 he was named manager of the gas apparatus department and two years later was appointed manager, distributor products, for Linde.

Alloy Rods Names Iverson

Einar Iverson AWS, of the Alloy Rods Co. Chicago office, has been named manager of the newly created Hard Surfacing Division with headquarters in York, Pa.

Mr. Iverson is a graduate of Rensselaer Polytechnic Institute with a B.S. in welding metallurgy. He has held positions as welding engineer for a number of fabricators and, since 1956, has been a field representative for Alloy Rods Co. He has served actively on many AWS committees and functions in the Chicago area.

Mr. Iverson's former territory in the Chicago area will be taken over by Robert Mann. Mr. Mann AWS, has been working as a field representative of the Chicago branch for the past year.

Lawrence Promoted by NCG

Appointment of Dorsey L. Lawrence AWS, as assistant district manager for the Milwaukee area has been announced by the National Cylinder Gas Division of Chemetron Corp. C. H. Reinecke AWS, is district manager.

Mr. Lawrence has been with the company since 1938 in sales, service engineering and dealer sales work.

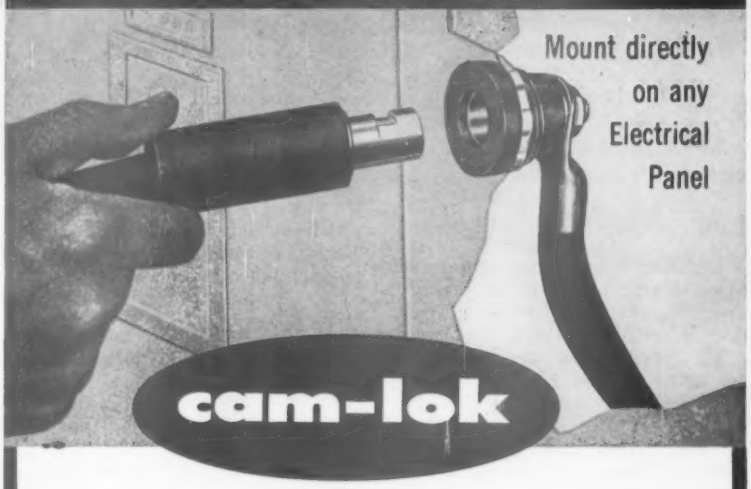
Pyromet Names McAuliffe

M. W. McAuliffe has been appointed San Francisco Bay Area sales representative of the Pyromet Co., South San Francisco, Calif.

His duties are to promote the brazing and heat-treating services of the Pyromet organization, reporting to Robert L. Ray, Pyromet partner and sales manager.

Before joining Pyromet, Mr. McAuliffe was manager of the cold finished bars and tubular products department of Joseph T. Ryerson & Son, Inc., Emeryville, and held other sales positions.

New Hi-Impact Plastic Insulated
Panel Receptacles and Mating Plugs



Now, you can make fast, positive power connections to any metal panel or housing without special insulating materials. Simply punch out a hole and insert a Cam-Lok self-insulated Receptacle! Uses standard electrical lock-nuts, affords "dead-front" protection. Push in and twist Cam-Lok mating Plug and you've made a locked connection, which can be released quickly.

New Cam-Lok Receptacles eliminate costs of special insulating panels and reduce assembly time. Patented, high-pressure contact assures minimum resistance and heating.

Cam-Lok has a complete line of Receptacles and Plugs in many sizes and designs. Standard and special purpose Power Distribution Connections are available. Write today for new Bulletin No. 301.

"Dead Front" design for fast direct mounting on . . .

• ELECTRICAL DISTRIBUTION PANELS • SWITCHGEAR
• BUS DUCT • JUNCTION BOXES
• WIREWAY or any electrical cubicle

cam-lok DIVISION

EMPIRE PRODUCTS, INC.
P.O. BOX J-98
CINCINNATI 36, OHIO

For details, circle No. 25 on Reader Information Card

Ed Bartz

Bartz Appointed Sales Manager

Ed Bartz has been appointed sales manager of Airline Welding and Engineering, 785 N. Prairie Ave., Hawthorne, Calif.

Mr. Bartz has served in an executive capacity with Airline Welding since August 1957, is a graduate of the Carnegie Institute of Technology and Westinghouse Electric Corp. engineering school and has been associated with various concerns in the manufacturing and sales of welding equipment.

He will be in charge of sales of Airline's longitudinal and circumferential weld positioner, and roll planishing equipment, Aronson rotating positioners and Herrick ram manipulators.

Edward Elliott, Jr.

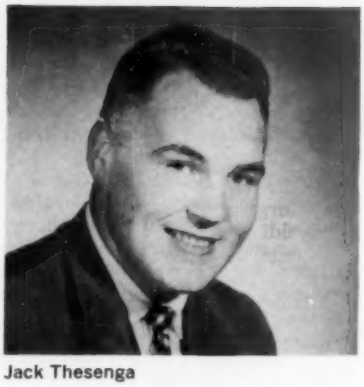
Elliot Made Liquid Carbonic Manager

Edward Elliott, Jr., has been named manager of industrial-medical sales by the Liquid Carbonic Division of General Dynamics Corp. He will be responsible for all of Liquid Carbonic's industrial-medical gas sales activities.

A graduate of Purdue University, Mr. Elliott was employed for 21 years by the Pressed Steel Tank Co. of Milwaukee, makers of tanks and pressure vessels for the gas industry. In wartime service with the Air Force he advanced to the rank of lieutenant colonel.

Before joining Liquid Carbonic he served as vice-president of the Cambridge Corp., then a division of Carrier Corp.

Clay E. Downing



Jack Thesenga

Sellstrom Mfg. Appoints Thesenga

Jack Thesenga has been appointed factory sales representative for Sellstrom Manufacturing Co., Palatine, Ill., in the Rocky Mountain area. According to the firm, manufacturers of face and eye protection equipment for the welding and safety fields, Mr. Thesenga will cover the states of Colorado, Kansas, Nebraska, Wyoming, Montana, North and South Dakota and neighboring Canadian provinces.

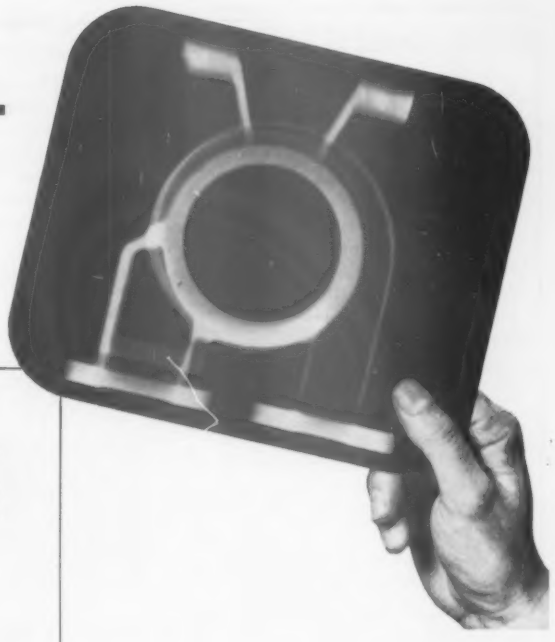
Haligas Named by Carol Cable

The appointment of Richard L. Haligas as Midwestern District manager has been announced by the Carol Cable Co., Pawtucket, R. I. Mr. Haligas makes his headquarters at 543 W. Emerson Ave., Glen Ellyn, Ill., where he will market arc-welding cable as well as other cord and cable products.

For details, circle No. 26 on Reader Information Card

Radiographs-

dry and ready-to-read in 13 minutes



KODAK INDUSTRIAL X-OMAT PROCESSOR

Now it takes only 13 minutes to process your industrial radiographs. The Kodak X-Omat Processor produces radiographs of uniform high quality . . . and it brings automation to your darkroom.

Exposed films are merely removed from their holders and fed directly into the processor. Film hangers are eliminated. And only 22 inches of the unit's 10-foot, 10-inch length need extend into the darkroom itself.

Kodak Industrial X-ray Films, Type AA and Type M—sheet films or continuous lengths—go through the system at the rate of 38 inches per minute.

This means time saved and costs cut. You should have the complete story. Send for the folder that gives all the details.

X-ray Division — EASTMAN KODAK COMPANY — Rochester 4, N.Y.

EASTMAN KODAK COMPANY, X-ray Division, Rochester 4, N. Y. 61-11

☐ Send the folder about the Kodak Industrial X-Omat Processor.

☐ Send the names of the Kodak Industrial X-Omat Processor dealers in my area.

Name _____

Firm Name _____

Firm Address (Street) _____

(City) _____ (Zone) _____ (State) _____

Mail this coupon for full information

Kodak

TRADE MARK

For details, circle No. 27 on Reader Information Card

WELDING ENGINEER

The Process Control function of the A. O. Smith Corporation at Milwaukee, Wisconsin has an opening for a Welding Engineer.

This man should be a college engineering graduate. It would be desirable that he have a few years experience in welding. His duties will enable him to work with the welding fabrication problems of light and heavy assemblies and will offer him diversified application of his abilities.

The salary is commensurate with his experience and ability.

Exceptional fringe benefits.

Send replies to:

D. H. Devine
A. O. Smith Corporation
Box 584
Milwaukee 1, Wisconsin

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Back of Reader Information Card

WELDING ENGINEER
ENGINEERING SERVICES DEPARTMENT
REYNOLDS METALS COMPANY
Richmond, Virginia

To advise and assist manufacturers and fabricators on aluminum welding problems. This includes demonstrating welding techniques and occasional training of customer weldors. Most activity in fusion processes but some resistance welding, brazing and soldering also involved.

Travel (approximately 50 per cent of working days) largely limited to U. S. Rarely out over week end.

Experience in aluminum welding and knowledge of equipment and procedures essential; metallurgical degree or training desirable.

Location, Richmond, Virginia—salary, open. Contact Paul E. Brandt, Director of Engineering Services, P. O. Box 2346, Richmond, Virginia.

Downing Made Assistant to Works Manager

R. W. Pearce AWS, works manager, of B-I-F Industries, Inc., announced the promotion of Clay E. Downing AWS, to assistant to works manager effective Aug. 24, 1959.

Mr. Downing joined B-I-F in 1948 as a product inspector and progressed to chief inspector and superintendent of quality control, a position which he will continue to hold in addition to his new duties. He is a senior member of the R. I. Section for Quality Control and program chairman of the Providence Section, AWS.

EMPLOYMENT SERVICE BULLETIN

Positions Vacant

Young Engineer Wanted. The Welding Research Council, a cooperative research organization, requires a young graduate engineer, having at least two years' experience, for Technical Secretary. Opportunities for advancement and experience in research writing and publications and contacts with outstanding scientists and engineers. Send résumé of education, experience and background to: Assistant Director, Welding Research Council, 29 W. 39th St., New York 18, N. Y. All replies will be held in confidence.

V-382. Welding Engineer to advise and assist manufacturers and fabricators on aluminum welding problems. This includes demonstrating welding techniques and occasional training of customer welders. Most activity in fusion processes but some resistance welding, brazing and soldering also involved.

Travel (approximately 50 percent of working days) largely limited to U. S. Rarely out over weekend.

Experience in aluminum welding and knowledge of equipment and procedures essential; metallurgical degree or training desirable.

Location — Richmond, Virginia. Salary open.

WELDING ENGINEERS

Bendix Aviation Corp., Kansas City Division, has excellent opportunities for welding engineers experienced in nonferrous fabrication. Applicants should have 5 years' experience in aircraft-type welding and brazing, with BS degree in welding or metallurgy. These engineers will work closely with factory personnel and suppliers as well as our own design engineers to develop new welding procedures, acceptance standards and quality controls.

Bendix offers capable men many professional and personal advantages. Highly progressive city features moderate climate, modern, uncrowded schools, short drive to work and many recreational and cultural attractions. Assistance program for advanced study at local universities if desired. Your inquiry strictly confidential. Send letter and résumé to:

Mr. T. H. Tillman,
Box 303-ME, Bendix
Kansas City, Missouri

Services Available

A - 724. Welding Supervisor. Thirty years in welding and related activities. Last eighteen in supervision, inspection and coordination of crafts. Thirteen years overseas with major companies. Heavy Code experience; high and low-alloy piping and vessels. Many processes. Prefer position in construction (foreign or domestic) field. Can assume heavy responsibility. Family man—good habits. Will relocate or travel. Resumé upon request.

OBITUARY

Richard McCoy

The death of Richard McCoy AWS, 40, welding sales engineer, is announced with regret by Metal & Thermit Corp. He died as the result of injuries received in an automobile accident.

Mr. McCoy joined the company in 1955 in the West-Central sales region. Prior to this, he worked for many years in the metalworking and construction industries. Surviving are his wife, four children and one grandchild.

Joseph Cagliostri

Joseph Cagliostri AWS, died on Sept. 5, 1959. He has been associated with Dresser Manufacturing Division at Bradford, Pa., since 1940 except for service with the U. S. Navy. He was a welding engineer there at the time of his death. A member of the Olean-Bradford Section of AWS since 1954, he was past section secretary and a director for the current year.

Gilbert D. Fish

Gilbert D. Fish, 65, died Sept. 7, 1959. He was a partner in the

SUPPORT YOUR SOCIETY....
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engineering firm of Seelye, Stevenson, Value & Knecht, 101 Park Ave., New York. Mr. Fish, a civil engineer, was widely known for his work in the construction of welded buildings and bridges. He taught mechanical engineering at Columbia and Yale universities and was a member of AWS and ASCE.

Horace B. Horton

Horace B. Horton, board chairman of Chicago Bridge & Iron Co., died on September 17th in Chicago. He was 73 years of age.

Mr. Horton was active in the affairs of the company founded by his father until being hospitalized several weeks ago. He had served as board chairman of the world-wide steel fabricating and construction firm since 1956.

Horace B. Horton

The oldest employee in length of service with the company, Mr. Horton joined CB&I in 1907. Five years later he was elected treasurer and a director. He was named president in 1945 and chairman of the board 11 years later. In addition to his duties with CB&I, he was a director of several subsidiary companies.

Mr. Horton was a member of the National War Labor Board from its organization in 1942 until the end of World War II. He also served on the Hoover Commission in 1954–55.

He was graduated from the University of Chicago in 1906 with a B.S. degree and took graduate work in engineering at the University of Illinois the following year. In 1942 he was awarded the honorary degree of Doctor of Business Administration by Thiel College, Greenville, Pa.

FOR ANY STAINLESS WELDING JOB

Drawalloy
CORPORATION

Stainless Steel Welding Wire

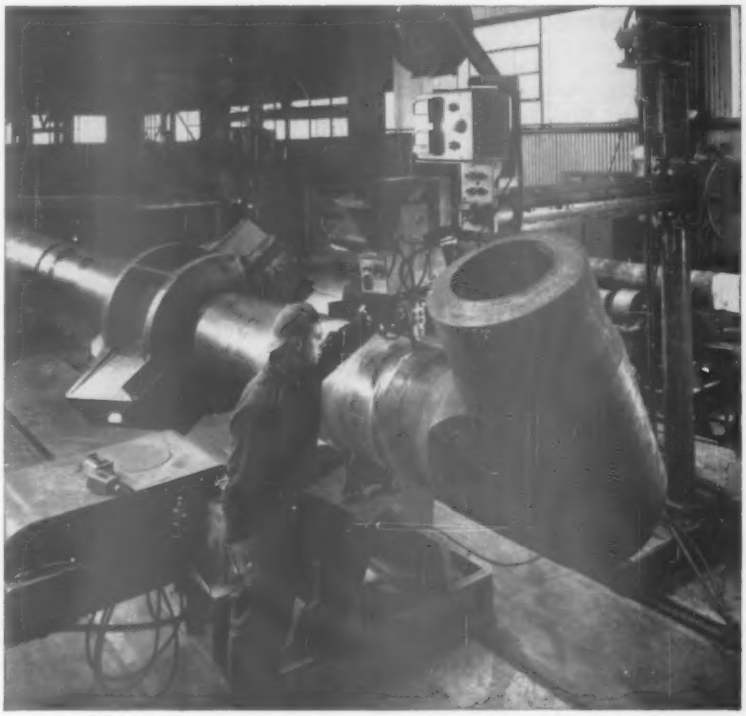


Photo courtesy of National Valve and Manufacturing Company, Pittsburgh, Pa.

Specify Drawalloy "quality controlled" stainless steel welding wire for *your* next "quality weldments." Your greatest advantage is experience . . . our experience in producing wires for welding exclusively. Because we are specialists, Drawalloy stainless steel welding wire is produced to strictly controlled specifications to provide the right chemistry, finish and temper for the finest quality weld metal and smoother operation in your automatic or semi-automatic equipment. Drawalloy stainless wires are available in all popular grades as well as 2¼ Cr, 1 Mo; 1¼ Cr, ½ Mo.

Why not discuss your stainless welding wire needs with your Drawalloy Distributor or Representative . . . a man with the products and knowledge to help you. Bulletin 355 DC provides complete information on every grade of Drawalloy wire. Write to: Drawalloy Corporation, Lincoln Highway West at Alloy Street, York 13, Penna.

DRAWALLOY
CORPORATION
STAINLESS STEEL & TOOL STEEL WELDING WIRE
THE WIRE MILL FOR THE WELDING INDUSTRY
For details, circle No. 28 on Reader Information Card

New Literature

ASA Booklet

Published as a handy reference for engineers, purchasing agents and business men who can benefit from learning how ASA activities are related to industry, this 52-page booklet describes current projects of the Association. Address American Standards Association, Dept. PR94, 70 East 45th St., New York 17, N. Y. Price per copy is 75¢ for members and $1.50 for nonmembers.

For details, circle No. 51 on Reader Information Card.

Cutting-torch Catalog

A new 12-page catalog on machine cutting torches, tips and accessories has just been issued by Air Reduction Co., Inc., 150 E. 42nd St., New York. This catalog represents the first consolidation of information on all of Airco's machine cutting torches in one publication.

The machine cutting torches described and illustrated in this catalog may be selected for use with oxygen and a fuel gas—acetylene, propane, natural or city gas—to give accurate flame cuts. Mounted on appropriate machines, and by selection of the proper torch, production quantities of straight-line and shape-cuts on steel sheets, plates, bars, slabs, blooms and billets, from $^1/_8$ to 48 in. or more in thickness may be produced.

For your free copy, circle No. 52 on Reader Information Card.

One-Man Hinged Closures

One-man hinged closures with built-in safety features for vacuum, low and high-pressure service in petroleum, gas transmission, chemicals and other industries are described in a new brochure available from Tube Turns Division of Chemetron Corp., Louisville 1, Ky.

Photographs illustrate one-weld installation, easy maintenance and one-man operation of the new Tube Turns' product. Charts give dimensional specifications and cross-sectional drawings describe design features of various sizes and types.

The Tube-Turn closures are produced in sizes from 2 through 42 in. for ASA 150, 300 and 600-lb service, with larger sizes and other pressure classes available on special order. Counter-balanced, spring-loaded types are offered for vertical applications in sizes 18 through 36 in. for ASA 150-lb service.

For your free copy, circle No. 53 on Reader Information Card.

Metalworking Bulletin

The 20-page September issue of Linde's "Metalworking Bulletin" includes articles on welded aluminum and stainless-steel boats and various applications of Linde Co. products to the solution of fabricating problems.

For your free copy, circle No. 54 on Reader Information Card.

Ampco Welding News

Recently issued, the 4-page bulletin no. 79, second quarter, 1959, "Ampco Welding News" features various applications of resistance, arc- and gas-welding products manufactured by Ampco Metal, Inc., Milwaukee 46, Wis.

For your free copy, circle No. 55 on Reader Information Card.

Booklet on "T-1" Steel

A 24-page booklet with illustrations and a slide-rule calculator is issued by the United States Steel Corp., 525 William Penn Place, Pittsburgh 30, Pa. Made especially for welders, the booklet describes some of the characteristics of "T-1" steel, the proper electrodes to be used in welding and the use of the slide rule in regulating heat input by welding speed, voltage and amperage control.

For your free copy, circle No. 56 on Reader Information Card.

Radiation-sources Brochure

A new 12-page brochure has been put out by Nuclear Systems Division, the Budd Co., Philadelphia 32, Pa., detailing its capabilities to provide radiation sources for irradiation research, radiography and teletherapy.

The publication illustrates and describes Nuclear Systems radioisotope encapsulation facilities—its hot cell has a 50,000 curie capacity—its training courses for new customers, and its lines of radiography, teletherapy and irradiation sources.

Also listed are the various types of radioisotopes available from Nuclear Systems.

For your free copy, circle No. 57 on Reader Information Card.

Hose-reel Ceiling Outlets

Hose-reel ceiling outlets for operating and recovery rooms are described in a new bulletin available from the National Cylinder Gas Division, Chemetron Corp., 840 North Michigan Ave., Chicago 11, Ill.

Photographs, drawing and diagrams show the installation and operation of the new single and multiple outlets which eliminate clutter and promote safety.

NCG bulletin NM-188 is called "NCG Hose Reel Ceiling Outlets."

For your free copy, circle No. 58 on Reader Information Card.

Resistance-welding Electrodes

Recently issued, a 1-page bulletin, no. 598-11, gives size and price details of the new tungsten-alloy resistance-welding electrodes produced by Saturn Metallurgical Industries, 475 Fifth Ave., New York 17, N. Y.

For your free copy, circle No. 59 on Reader Information Card.

Weld-It

Bulletin no. 591, "Weld-It," has been issued by the Taylor-Winfield Corp., Warren, Ohio. Four pages with illustrations present ideas on planned package production using T-W designed forming and welding presses.

For your free copy, circle No. 60 on Reader Information Card.

Studies in Metallurgy Released

Three reports have been released to industry through the Office of Technical Services, U. S. Department of Commerce.

"Testing for Notch Sensitivity in Welded Joints." C. E. Hartbower, Watertown Arsenal, U. S. Army Ordnance Corps., (no date), 24 pp., (order PB 151630 from OTS, U. S. Department of Commerce, Washington 25, D. C., 75 cents). A critical review of selected papers dealing with the evaluation of notch toughness in steel by means of the V-notch Charpy impact test is presented.

"Survey of Literature on the Effect of Testing Temperature on the Properties of Wrought Copper

Base Alloys." H. R. Pritchard, Frankford Arsenal, U. S. Army Ordnance Corps., Feb., 1958., 92 pp., (order PB 151306 from OTS, U. S. Department of Commerce, Washington 25, D. C., $2.25). A survey of literature was made to correlate data on the effect of testing temperatures in the range −300 to 1500° F on the properties of wrought copper-base alloys.

"Proceedings of Industrial Technology Conference on Metals Processing: 16-17-18 October 1957," Watertown Arsenal, U. S. Army Ordnance Corps., 392 pp. (order PB 151308 from OTS, U. S. Department of Commerce, Washington 25, D. C. $5.00). The agenda, abstracts and papers presented at the 3-day Industrial Technology Conference on Metals Processing, held at the Army's Watertown Arsenal in October 1957, are included in this report.

For details, Circle No. 64 on Reader Information Card.

Metal-cleaning Handbook

"Some *More* Good Things to Know About Metal Cleaning," just published by Oakite Products, Inc., 19 Rector St., New York 6, N. Y. contains 28 pages of information regarding metal cleaning and treating fields.

The booklet discusses the chemistry and techniques of cleaning; tank cleaning, with suggestions for tank design and layout and selection of detergents; electrocleaning; barrel cleaning; machine cleaning; and ultrasonic cleaning. There are illuminating discussions of the relative advantages of iron and zinc Oakite CrysCoat phosphating processes and ChromiCoat aluminum conversion coatings as prepaint treatments. The book also describes pickling, deoxidizing and metal etching treatments; prevention of rust between operations and in storage; paint stripping; and paint spray booth water curtain additives

For your free copy, circle No. 61 on Reader Information Card.

Stainless-steel Brazing Guide

Just released by Harper Electric Furnace Corp., 39 River St., Buffalo 2, N. Y. a new illustrated booklet, "How to Braze Stainless Steels," discusses in detail four important aspects of the brazing process: characteristics of base and filler metals; brazing cycles; selecting and using gas atmospheres; construction and application of various types of furnaces.

The author, H. M. Webber, AWS is manager of process engineering for Harper.

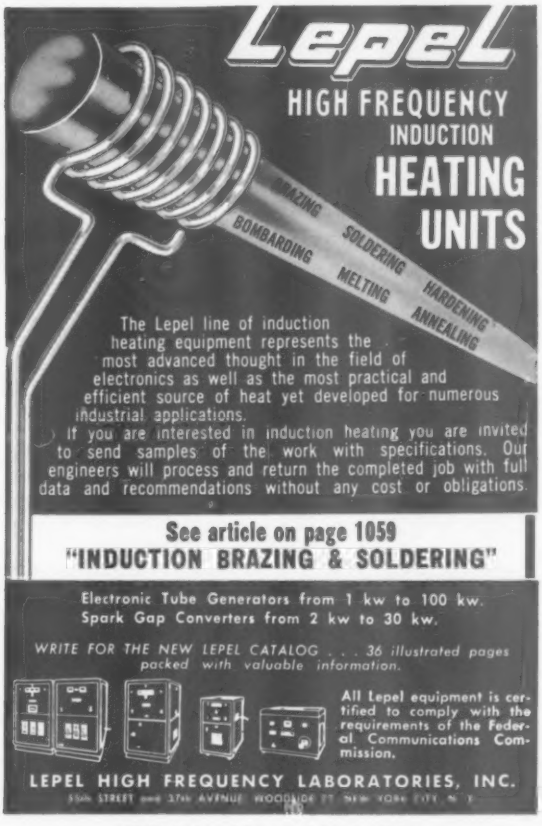
For your free copy, circle No. 62 on Reader Information Card.

Metalspray Powder

A new 8½ x 11 illustrated 2-color Engineering Data Sheet (No. 57) describing the new Colmonoy C-290 crankshaft metalspray powder is now available from Wall Colmonoy Corp., 19345 John R St., Detroit 3, Mich.

The data sheet discusses the physical properties and characteristics of the patented material and illustrates with photos some of the steps in its application. A complete step-by-step application procedure is also included.

For your free copy, circle No. 63 on Reader Information Card.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UNITS
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The Lepel line of induction heating equipment represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for numerous industrial applications.
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See article on page 1059
"INDUCTION BRAZING & SOLDERING"
Electronic Tube Generators from 1 kw to 100 kw.
Spark Gap Converters from 2 kw to 30 kw.
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Handy Comparison Chart for metal hardness on all Rockwell and Brinell Scales
LOW COST PORTABLE STEEL HARDNESS TESTER
A compact metal hardness tester for determining the hardness of steel alloys and other metals in the range of from 25 to 65 Rockwell "C" Scale.
CAN BE USED ON STEEL STRUCTURES, TANKS, PIPES, ETC., BY:
✓ WELDERS, MAINTENANCE, FIELD AND PLANT ENGINEERS.
✓ ALSO FOR TESTING PARTS OF STANDARD OR SPECIAL WELDING SEGMENTS.
TEST SET INCLUDES:
Micro ball indenter, measuring microscope, standard hardness Test Block, Carrying Case, Instructions.
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IF NOT IN YOUR DEALER'S STOCK, ORDER DIRECT FROM DEPT. WJ-119
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For details, circle No. 30 on Reader Information Card

New Products

Cable Connector

Threaded Power Connection (T.P.C.) is the name given to a new development in connecting welding cable to accessories by Lenco, Inc., 350 West Adams St., Jackson, Miss., makers of Hi-amp series of electrode holders and ground clamps.

One end of a soft copper sleeve is threaded. Insulation is removed from the welding cable to allow the bare copper wire to extend approximately one-half inch through the sleeve and the sleeve is crimped onto the welding cable. The threaded sleeve is then screwed into a threaded socket on the accessory, pushing the bare end of the cable into the socket depth, completing the electrical connection.

For details, circle No. 101 on Reader Information Card.

Liquid-oxygen Manifold

A new manifold introduced by Linde Co., Division of Union Carbide Corp., 420 Lexington Ave., Room 2840, New York 17, N. Y. features automatic changeover of liquid-oxygen cylinders. Used with four Linde LC-3 liquid-oxygen cylinders, the new Oxweld M-40 provides an uninterrupted supply of 12,000 cu ft of oxygen. More than 48 conventional high-pressure cylinders would be needed to supply the same amount of oxygen. The new unit occupies only a fraction of the space required for an equivalent high-pressure cylinder supply.

Designed for industrial or hospital use, the new manifold is expected to find widespread use as a replacement for many existing systems of high-pressure cylinder oxygen supply.

For details, circle No. 102 on Reader Information Card.

Safety Gloves

Air Reduction Sales Co., 150 E. 42nd St., New York 17, N. Y., has recently placed on the market four new types of safety gloves for light welding work and general industrial work requiring some safety protection.

Made of heat-resistant leather the four types are known as E-GR, D-SS, AR-1 and GR-SS.

For details, circle No. 103 on Reader Information Card.

Light X-ray Unit

X-ray inspection of pipeline section and "window welds" is now more easily accomplished with the use of new lightweight, portable X-ray equipment, according to an announcement by X-Ray Department, General Electric Co., Milwaukee, Wis. Use of high-voltage portable X-ray equipment makes inspection of these weldments possible in places where larger, bulkier X-ray equipment would be impractical.

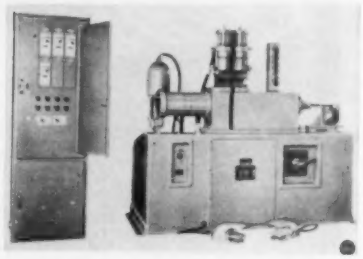
The new General Electric LX-140 portable X-ray unit weighs only 46 1/4 lb. The control unit weighs only 25 lb and both ship in a shockproof case which measures only 26 x 24 x 18 in.

A continuous range of 70 to 140 kvp is available. Radiographs with 2% sensitivity and 1.5 density can be produced with 1 1/2 minute exposure through 1 1/4 in. of steel. The new unit will operate in temperatures ranging from 0 to 120° F, humidity up to 95% and altitudes up to 5000 feet with ample effective radiation protection provided.

For details, circle No. 104 on Reader Information Card.

Light Ram Design

Drag caused by the weight of heavy metal rams and by friction is eliminated by a lightweight, aluminum ram operating in a lineal ball-bearing sleeve on the Universal Electroweld single-phase butt welding machine, according to the Universal Electroweld Division, Electric Arc, Inc., 152-1 Jelliff Ave., Newark 7, N. J. Descriptive literature is available for this and the entire line of resistance-welding machines.

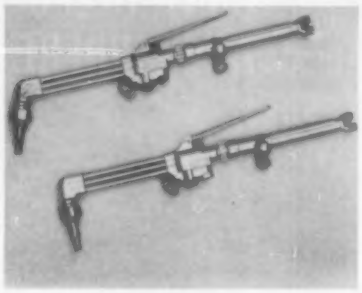


For details, circle No. 105 on Reader Information Card.

Lightweight Cutting Assembly

A new lightweight cutting assembly, which permits the use of "slip-in" tips, has been developed by Smith Welding Equipment Corp. 2619 Fourth St. S.E., Minneapolis 14, Minn. for its Airline torch.

The addition of this assembly completes the conversion to slip-in



tips of all current Smith's torches. Slip-in tips are said to eliminate the need for wrench tightening.

Two models of the "300" have been introduced—the AC305 with a 75-deg head, and the AC309 with a 90-deg head.

For details, circle No. 106 on Reader Information Card.

Helmet Lift-front Retainer

An improved lift-front plate retainer molded of rugged nylon plastic has been developed for its premier line of welding helmets by Sellstrom Manufacturing Co., Palatine, Ill.

In addition to its large plate capacity, the new retainer boasts firm plate retention with a completely new spring system. Plate changing is said to be simple; the retaining spring is readily accessible and snaps out as desired. The lift part uses coil springs to maintain a firm open position, closing positively to insure against light leaks. By adjusting two screws, plate retainer can be interchanged.

For details, circle No. 107 on Reader Information Card.

Metallizing Gun

A lightweight, heavy-duty metallizing gun has been announced by SpraRod Corp., 5795 E. 83 St., Cleveland 4, Ohio.

The principal feature of the gun is a two-position air cap which is said to adjust automatically for easy lighting and fast, fine-grain spraying.

For details, circle No. 108 on Reader Information Card.

Gas-welding Equipment

National Welding Equipment Co., San Francisco, Calif., announces a new and attractively packed welding and oxygen-cutting outfit so arranged that it may be purchased with or without accessories, such as hose, goggles, spark lighters or with these accessory items, including either a $12^1/_2$ or a 25 ft length of twin hose. This arrangement makes it easier for the distributor who might or might not need to include these accessory items when the sale is made to the ultimate user.

The outfit may be extended, when need arises, to include a variety of additional welding, multiflame heating and brazing nozzles in various sizes and cutting tips for differing applications and metal thickness.

The cutting attachment has a cutting range of 4 in. of metal thickness. All of the nozzle types and sizes fit, with appropriate mixer, the company's larger welding-torch model.

The regulators included in the outfit are of standard National Welding Equipment Co. design.

For details, circle No. 109 on Reader Information Card.

NATIONAL CARBIDE
IN THE RED DRUM

HIGHEST QUALITY

DUST FREE

DEPENDABLE SUPPLY

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AT THE FRONTIERS OF PROGRESS YOU'LL FIND AN AIR REDUCTION PRODUCT
For details, circle No. 31 on Reader Information Card

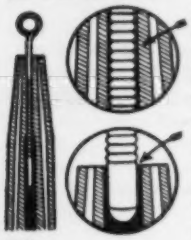
World's Finest CUTTING and WELDING TIP CLEANERS

WYPO WIRES AND POLISHES

YOU GET SO MUCH MORE IN WYPO Made of Stainless Steel

DOUBLES THE LIFE OF YOUR WELDING AND CUTTING TIPS

The exclusive circle design found only in Wypo Cutting and Welding Tip Cleaners provides as many as 60 more cleaning edges per inch of cleaner.



These rounded outer edges of cleaning ridges clean and polish tip orifice without scratching or cutting.

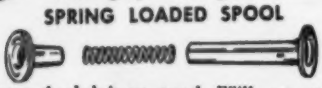
This smooth pilot guides WYPO Tip Cleaner into tip Will not enlarge or damage tip port.

This cross section view of WYPO Cleaning Surfaces shows these exclusive features:

Rounded cleaning surfaces that won't jam or cut.

Straight sided valleys insure thoro cleaning by removing all waste.

SPRING LOADED SPOOL



Spring loaded brass spool. Will not rust. Holds cleaners securely in case.

DOUBLE WOUND EYES

Insures longer life for small sizes of WYPO Tip Cleaners. Will not pull out of case.

NOW AVAILABLE IN 3 CONVENIENT SETS

WYPO TIP CLEANERS STANDARD SET	
CLEANER NO.	FOR DRILL
7	75-74
8	73-72-71
10	70-69-68
12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51-50 49

MADE IN U.S.A.

PAT NOS 2629581 2673758 IN CANADA 1948

STANDARD SET OF (13) Cleans (12) Drill Sizes Nos. 75 to 49 Incl.

WYPO TIP CLEANERS JUMBO SET	
CLEANER NO.	FOR DRILL
28	48-47
30	46-45
32	44-43
34	42-41
37	40-39-38
39	37-36
42	35-34-33
44	32-31
45	30

MADE IN U.S.A.

PAT NOS 2629581 2673758 IN CANADA 1948

JUMBO SET OF (9) Cleans (19) Drill Sizes Nos. 48 to 30 Incl.

MASTER SET	
CLEANER NO.	FOR DRILL
7	75-74
8	73-72-71
10	70-69-68
12	67-66-65
14	64-63-62
15	61-60
16	59-58
17	57
18	56
22	55-54
24	53-52
26	51 50-49
28	48-47
30	46-45
32	44-43
34	42-41
37	40-39-38
39	37-36
42	35-34-33
44	32-31
45	30

MADE IN U.S.A.

PAT NOS 2629581 2673758 IN CANADA 1948

MASTER SET OF (21) Cleans (16) Drill Sizes Nos. 75 to 30 Incl.

WYPO TIP CLEANERS IN CANADA 1948

Replacement cleaners available. Cleaning Range —Cleaner No. & Drill Nos. stamped on back of each case. WYPO GIVES YOU MORE!

SOLD BY LEADING WELDING SUPPLY DEALERS

WYPO MAITLEN AND BENSON, INC. 1345 George St., Long Beach 8, Calif.

For details, circle No. 32 on Reader Information Card

Silver-brazing flux

Greater heat tolerance and outstanding coverage per pound of material are said to be featured in the new general purpose silver-brazing flux just introduced by Special Chemicals Corp., 100 South Water St., Ossining, N. Y.

Free working samples for use in the 1100 to 1700° F range may be had.

For details, circle No. 111 on Reader Information Card.

Grinder Reclaims Flux

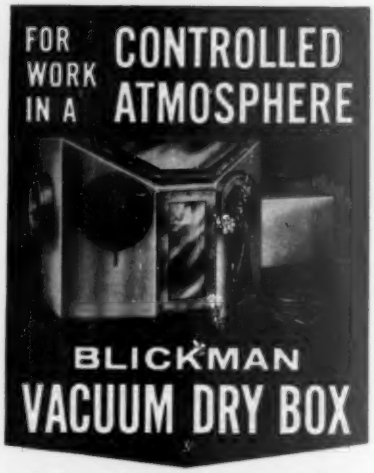
A new submerged-arc welding-flux grinder, the model RG-1, is now available from L & B Welding Equipment, Inc., 2424 6th St., Berkeley, Calif. The initial cost of this machine will be returned after only 12,000 lb of flux has been reclaimed, it is reported by the manufacturer. Features of this unit are said to be: processes over 1500 lb of fused flux per hour; air-blower system suppresses dust to a minimum; magnetic separator; hardfaced roll crushers; low flux losses; patented self-cleaning screen-rotation insures long life; continuous circulation eliminates rehandling; totally enclosed 3 hp motor; both roll crushers powerized; heavy-duty sealed roller bearings utilized throughout; adjustable spring-loaded crushers; small floor area required; rugged heavy-duty construction.

For details, circle No. 112 on Reader Information Card.

Seam-welding Machine

An improved line of seam-welding machines is covered in a new bulletin, S-59, offered by The Federal Machine and Welder Co., Warren, Ohio. In color, this illustrated brochure gives complete description and specifications covering the three available stock sizes ranging in capacity from 50 to 400 kva.

For details, circle No. 113 on Reader Information Card.



Designs and specifications are available for a variety of welding enclosures for research and production welding, and for work in the fields of metallurgy and physical chemistry. These enclosures can be fully evacuated and then be filled with an inert gas for welding in an inert atmosphere. Write for Technical Bulletins on various types of welding enclosures: S. Blickman, Inc., 3011 Gregory Avenue, Weehawken, N. J.

BLICKMAN
LABORATORY EQUIPMENT

Look for this symbol of quality Blickman-Built

For details, circle No. 29 on Reader Information Card

Circular Slide Rule

General Industrial Co. offers a circular slide rule for engineers and for other plant and office executives. Any executive who must perform simple calculations will find this convenient, pocket-size calculator extremely useful in his work.

For your free circular slide rule

write on your business letterhead to General Industrial Co., 1788J Montrose Ave., Chicago 13, Ill. Those who do not qualify as an engineer or business executive can receive a slide rule by sending 50 cents.

For details, circle No. 114 on Reader Information Card.

Cool Safety Shield

For operations related to welding, American Optical Co., Southbridge, Mass., offers the "Kool-Vent," a

shield with an acetate window set in a 24-mesh metal screen.

For details, circle No. 115 on Reader Information Card.

Dual-output Induction Heater

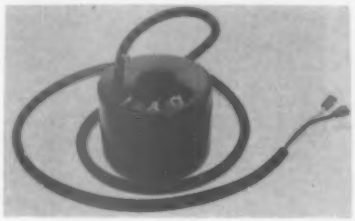
A portable induction-heating unit featuring two output coaxial cables, each of which has a work coil and a pendant type control box, permits operation at a distance up to 50 ft from the generator, according to Induction Heating Corp., 181

Wythe Ave., Brooklyn 11, N. Y. The separate work coils are operated alternately making possible a 100% utility of this Ther-Monic heater which is also described as an electronic type with self-contained cooling.

For details, circle No. 116 on Reader Information Card.

Relay Actuator

L. and B. Electronics, 2424 Sixth Ave., Berkeley, Calif., announces that a new concept in current relay actuation, the L and B Relay Actuator, senses the magnetic field created by the current in the wire that is placed through the hole in the toroid. This unit can give relay



actuation as low as 4.5 amps, depending on the characteristics of the relay used. The actuator has no moving parts, eliminates mechanical timers normally used in such applications as welding, and has *no* upper current limitations. This unit can be used for alternate and direct-current systems.

For details, circle No. 117 on Reader Information Card.

Plastic Lens

The Thermacote Co., 108 South DeLacey Ave., Pasadena, Calif., announces an all-plastic weldors' cover lens that is being sold under the trade name "Sta-Kleer."

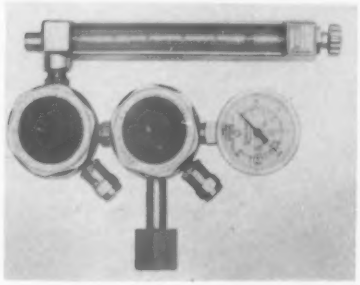
It is stated that this new product will give 40% more life with no increase in cost.

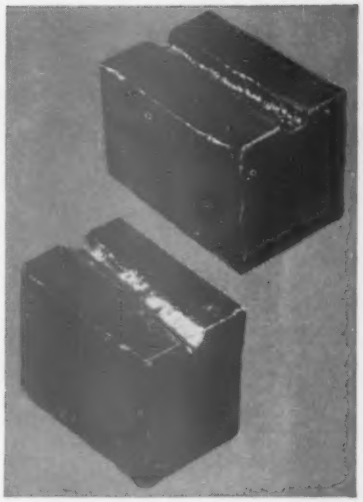
For details, circle No. 118 on Reader Information Card.

Flowmeter Regulators

Savings in argon and helium used in shielded inert-gas welding processes are promised with new flowmeter regulators developed by Smith Welding Equipment Corp., 2633 Fourth St., S. E., Minneapolis 14, Minn.

According to the manufacturer, the advantage is derived from the combination of their special two-stage Econoflow regulator and the separate direct-reading flowmeters





Which stainless steel block was grooved in 12 seconds?

It took 10 minutes to chip a ¼" deep, ⅜" wide groove in this 3¼" long stainless steel block on the left. Arcair did a better job in just 12 seconds . . . or ⅓₀th of the time. (See block at right.) Groove is 5/16" deep; 7/16" wide. Both blocks were cut from the same stainless.

You can groove, cut, gouge or bevel *any* metal faster with Arcair . . . get significant cost savings. Yet, the Arcair process costs less than $100.

HOW DOES ARCAIR WORK? The torch uses 80 p.s.i. air, welding machine current and special electrodes to melt and instantly blow away metal. There's no oxidation. New operators learn everything in 15 minutes.

WHAT'S YOUR PROBLEM? Write us. Without obligation, we will recommend correct torch and method to help you cut costs. (Or, call your Arcair welding supply distributor.)

Arcair

THE ARCAIR CO.,
431 S. Mt. Pleasant St., Lancaster, Ohio
Send me more information on Arcair Torches and special electrodes.

NAME _____ TITLE _____
COMPANY _____
ADDRESS _____
CITY _____ STATE _____
MY PROBLEM _____

For details, circle No. 33 on Reader Information Card

said to be correct within 2% of full-scale reading. The flowmeter's accuracy is said to lie in an extra long tube and a unique center guide for the ball float.

For details, circle No. 119 on Reader Information Card.

Scarfing Torch with Universal Mixer

A new hand scarfing torch with a universal mixer that enables it to operate on either acetylene or fuel gas has been introduced by Linde Co., Division of Union Carbide Corp., 420 Lexington Ave., New York 17, N. Y. Known as the Oxweld C-65 the new scarfing torch is equipped with a starting rod feeder which is said to provide quicker starts and to prevent the formation of "fins" by eliminating normal preheat time. Designed for removing surface defects from steel ingots, billets, blooms and slabs prior to final rolling, the new torch is ideal for use on large-size seamless steel rounds.

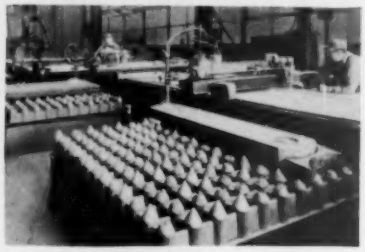
Nozzles used with the new torch are designed to produce a broader low-velocity oxygen stream, increasing the width of the area that can be scarfed in a single pass of the torch. Specially designed nozzles used with the C-65 Torch are shorter ($4\,^9/_{16}$ in. long) than conventional nozzles increasing their rigidity and increasing nozzle service. Torch heads are reinforced at wear points with a special Haynes stellite alloy.

For details, circle No. 120 on Reader Information Card.

Oxygen-Cutting Table

The Cleveland Crane & Engineering Co., Wickliffe, Ohio, is introducing a flame-cutting table designed to overcome the high cost of repairing and replacing tables used for supporting plate during oxygen-cutting.

It is made of cast iron and machined to accommodate low cost, replaceable, cast-iron cones. Plates rest on the cones while being cut. Cast iron is used because it has proved highly resistant to heat damage.



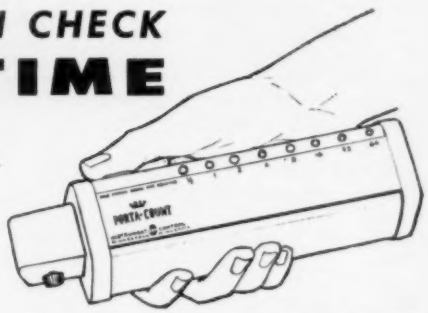
For details, circle No. 121 on Reader Information Card.

INSTRUCTIONS FOR PROSPECTIVE AUTHORS

Authors who plan to submit papers for publication in the Welding Journal are invited to send for a free copy of the booklet "Instructions and Suggestions for Authors." All requests should be addressed to Editor, Welding Journal, American Welding Society, 33 W. 39th St., New York 18, N. Y.

For details, circle No. 35 on Reader Information Card →

NOW YOU CAN CHECK
WELD TIME
Accurately
Quickly
with
the



$282.00

***NEW* PORTA-COUNT** cycle counter

It counts AC cycles of weld time to an accuracy of ±½ cycle and it will count up to 127 cycles. This permits a rapid, easy check of settings on welder controls. Light and small enough to carry conveniently right on the job, to assure getting proper weldtime to provide perfect welds every time.

PORTA-COUNT is a binary counter providing a reading by means of a display of lights. Accuracy is 100%. An automatic reset is incorporated in the circuit.

PORTA-COUNT is completely portable and operates on its own self-contained long life batteries. No power connection or battery pack is needed. Design is compact, so that it fits easily in the hand.

INDUCTION PICK-UP

No clips...no plug in...no clamp on.

PORTA-COUNT uses inductive pick up sensing the magnetic field around the welding buss, transformer, or at electrodes of the welder. Complete absence of any connecting leads greatly simplifies and speeds the counting of weld time.

Circuit is completely transistorized for rough treatment in industrial plants. All components are rigidly mounted on a reinforced bakelite foundation plate, for ruggedized assembly that will take any amount of abuse.

INSTRUMENT CONTROL COMPANY
1554 C NICOLLET AVENUE, MINNEAPOLIS 3, MINN.

For details, circle No. 34 on Reader Information Card

LINCOLN WELDERS

"IDEALARC TIG"

AC & AC/DC ARC WELDERS

AC High Freq. for Tungsten Inert Gas

DC High Freq. for Tungsten Inert Gas

DC for Manual Electrodes

AC for Manual Electrodes

Remote Control For Crater Filling

Balanced Wave Filter for Superior AC High Freq. Operation

SELECT ANY OR ALL OF THESE FEATURES IN THE NEW "TIG" MODELS

1

AC Inert Gas

DC Inert Gas

AC Manual Electrode

DC Manual Electrode

ONE MACHINE

...FOR ALL MANUAL ARC WELDING APPLICATIONS

Now for the first time, users of arc welding can obtain a machine tailored to their own specific needs at the low cost of volume production equipment.
Two 300 ampere models, AC and AC/DC, can be equipped with High Frequency with gas and water controls, or any other feature required, at the factory. The buyer is free to select only those features he needs, thereby eliminating needless expense of purchasing unnecessary capabilities.

BASIC EQUIPMENT

The heart of the Idealarc TIG welder is a completely new saturable reactor transformer welder with plenty of capacity and exceptional arc characteristics. It is an excellent AC arc welder capable of handling a wide range of AC arc welding applications. This straight AC Idealarc is known as Model TIG-300.

The TIG-300/300 AC/DC Idealarc is actually the same high-quality AC welder with rectifiers, line contactor and other necessary circuitry added. This model has the same excellent AC welding characteristics, plus DC—at the flip of a switch.

The following features make either type Idealarc TIG welder an outstanding machine.

SELECTOR SWITCH

The selector switch on the combination AC/DC models has DC+, DC— and AC positions. A new design, it is rugged and capable of standing heavy use under severe conditions.

CONVENIENT CURRENT CONTROL

A selector switch divides the TIG's 10 - 375 ampere output into three easily adjusted narrow ranges:

	Position 1	Position 2	Position 3
AC amps.	10 to 75	40 to 250	125 to 450
DC amps.	10 to 70	45 to 250	170 to 375

A rheostat control provides fine tuning within each range. Further, all machines accommodate remote current controls.

OVERLOAD PROTECTION

All AC/DC Idealarcs and all straight AC's equipped with line contactors have built-in overload protection. This prevents damage to the welder from excessive heat in the windings or rectifier, regardless of the source of heat.

INDICATOR LAMP

A red light provides a visible signal that the welder is turned on. This lessens the chance that the machines will be left on overnight or over the weekend when they should be turned off.

RECESSED CONTROL PANEL

The entire face of the machine is recessed to prevent accidental damage to the controls. Output studs are recessed still further to give added protection against accidental short circuits across them.

STRAIN RELIEF LOOP

A rugged strain relief loop under the output terminals restrains excessive tension on the cable to prevent loosened contacts, arcing and cable overheating at the studs.

AMPLE COOLING

A large fan forces quantities of clean air from the top of the welder down over rectifier stacks and windings and out the bottom. This provides ample rectifier cooling without sucking dust and dirt from the floor through the machine.

Every "Idealarc TIG" Welder Has All These Features

Basic Price

AC Only $360 AC/DC $625

CONVENIENT MAINTENANCE

Maintenance personnel really appreciate the accessibility and ease of maintenance of the Idealarc TIG models. The sides of the machine remove easily and individually for routine inspection and cleaning. All parts are readily accessible-

SINGLE PHASE POWER

The Idealarc TIG welder can be used on any type of AC power source because it is a single phase machine. It is not limited to three phase power supply.

CONNECTS TO TWO VOLTAGES

All TIG model welders for 220/440 volts or 220/550 volts are reconnectable. On machines with line contactors this is done without changing any leads by merely moving a contact plate. The panel automatically reads the voltage for which it is connected.

OPTIONAL EQUIPMENT

Optional equipment converts the basic TIG-300 or TIG-300/300 Idealarc welder into a deluxe machine for all types of tungsten inert gas welding. Other features provide added convenience in using the machine. All may be factory-installed as integral parts of the machine and some are also available as a kit for field installation.

HIGH FREQUENCY And INERT GAS CONTROL

This feature provides all controls necessary for any tungsten inert gas welding. It can be set to operate in any of the following ways with either AC or DC:

Select Any or All These Optional Features

Price Including All Options
Except 115V Pushbutton and Undercarriage
AC $816 AC/DC $1041

1. High frequency, continuous during arc time, with gas and water control.
2. High frequency for arc start only, with gas and water control.
3. No high frequency, but water and gas control.
4. No high frequency, no water and gas control.

Two switches provide the above choices. The first is a master switch that turns the whole high-frequency unit, including gas and water controls, on and off. When it is in the "on" position, the second switch selects continuous spark, start-only spark or no spark without affecting the gas and water controls.

A timer adjusts the gas and water after-flow time. It is set according to electrode size.

There is no welding power or high-frequency output, except when welding. Cable and torch are electrically, "cold" and safe. To weld, the operator depresses a remote switch which attaches to the torch. This closes an output contactor to apply high-frequency and welding current. When the arc is extinguished, the contactor opens automatically.

REMOTE CURRENT CONTROL

With the convenient Amptrol remote current control, operators adjust current while welding to compensate for varied welding conditions and for crater filling. It controls current from minimum amperage of the range set on the machine to the maximum amperage set on the fine tuning control. It comes with 25 feet of electrical cord and a three-pronged plug which fits the receptacle on the welder. Amptrol is available in either hand- or foot-operated models.

BALANCED WAVE FILTER

Recommended when an AC high frequency is used, the filter eliminates the distorted wave shape and DC feedback current created by the arc. It provides smooth operating characteristics over the entire current range and maintains the machine's rated output at 50% duty cycle. It includes three, 6-volt automotive storage batteries and a trickle charge circuit to keep them fully charged. Equipped with a switch, the trickle charge can be turned off when not needed. A quickly detachable (QD) connector is provided to take batteries out of welding circuit when not required.

POWER FACTOR CORRECTION CONDENSERS*

Power factor condensers improve power factor and reduce input current. With them, it is possible to install lighter input leads and reduce KVA power demands.

LINE CONTACTOR

You start the Idealarc TIG with a pushbutton on the front of the machine. This operates a magnetic contactor type starter, which is connected to provide overload and overheating protection for the rectifier and windings. The line contactor is standard equipment on AC/DC models; optional on straight AC models.

115 VOLT PUSHBUTTON CONTROL

This feature modifies the pushbutton circuit on the line contactor so it meets special safety regulations which require that pushbuttons operate only in 115 volt circuits.

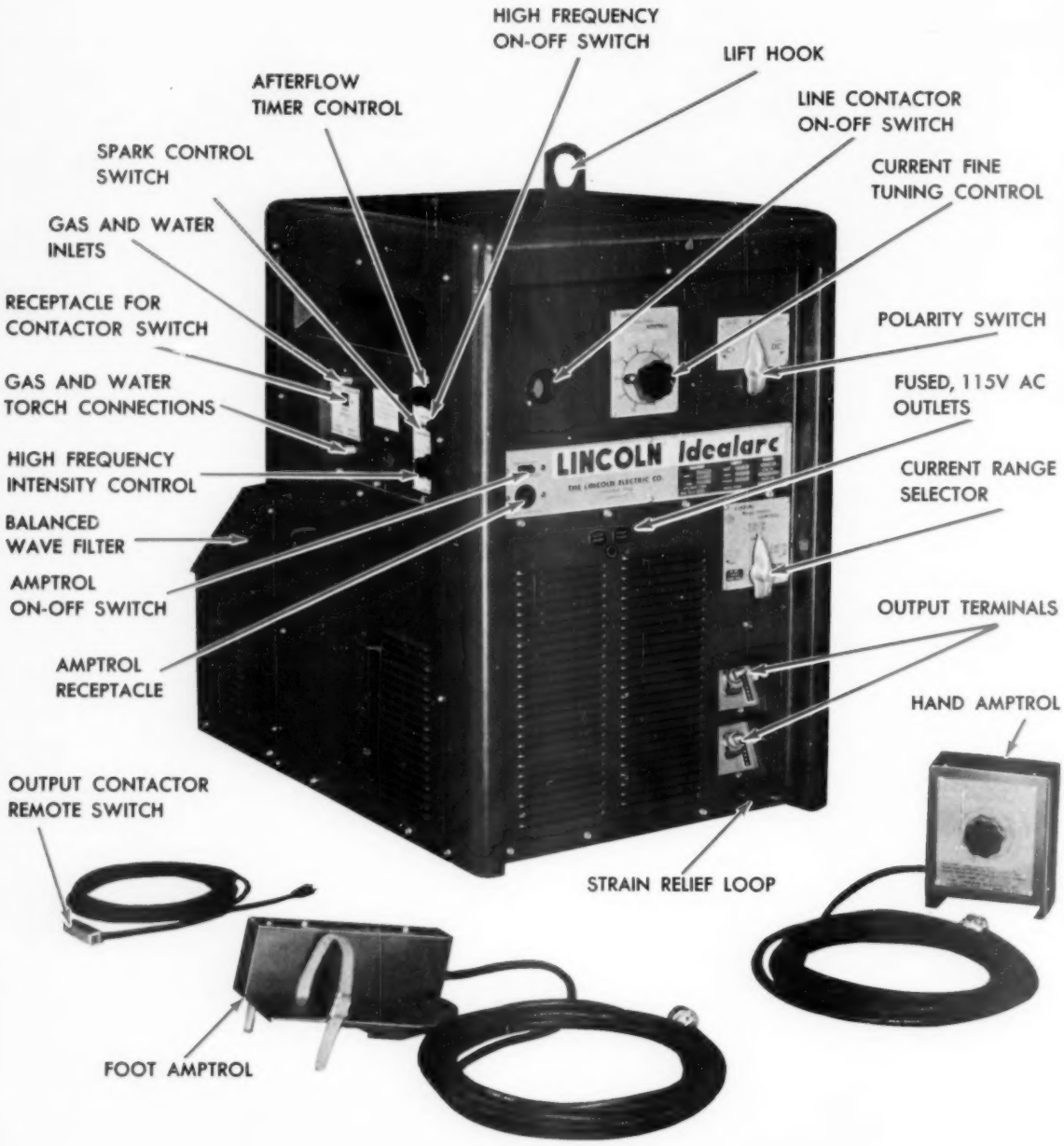
UNDERCARRIAGES*

Heavy duty, three-wheeled undercarriages provide convenient portability for machines that frequently move from one place to another in the shop. Available with either steel or solid rubber tired wheels, the undercarriage pulls easily and requires little extra floor space beyond that required for the welder itself.

* Available in a kit for field installation.

† Zone 1 Prices

Lincoln "Idealarc TIG" Arc Welder



FOR ALL MANUAL ARC WELDING APPLICATIONS

APPLICATIONS

Idealarc TIG welders are exceptionally versatile welding machines. No other welder offers all the features available on these Idealarcs. No other machine can do so many arc welding jobs.

First, Idealarc TIG welders are especially applicable to tungsten inert gas welding of aluminum and other newer metals with AC and high frequency. The output characteristics are designed to provide an even wave shape that produces best arc characteristics and cleaning action. The wave filter automatically maintains these characteristics over the entire current range. This filter is the most simple and effective means of controlling the DC component in use today.

All necessary controls for tungsten inert gas welding are integral parts of the high frequency package. Smooth remote control, so necessary in crater filling, is available. In short, Idealarc TIG welders have everything required in a machine for AC, high frequency, inert gas welding.

Further, direct current with high frequency is used for tungsten inert gas welding of stainless and some alloy steels. Idealarc TIG welders are ideal for this type of work too. Again, they have everything necessary to do the job.

In addition, Idealarc TIG is an excellent machine for all conventional, coated electrode, applications. AC or DC, convenient controls, good arc characteristics, ample current range, and many other features provide plenty of operator appeal and outstanding welding performance. Job shops and maintenance departments particularly appreciate the ability to handle, with one machine, both their routine work and the aluminum or other special jobs they encounter.

Idealarc TIG is truely an exceptionally versatile machine for both inert gas and conventional electrode welding.

(Note: If your welding requires only conventional coated electrodes, see Bulletin 4607.1 which describes the model TM Idealarc welder.)

SPECIFICATIONS

Model	TIG-300	TIG-300/300
Type 60 cycle	K-1130	K-1131
50 cycle	K-1132	K-1133
NEMA Output		
Amperes	300	300
Arc Voltage	40	40
Duty Cycle	60%*	60%*
Output Current Range		
AC	10-450 amps.	10-450 amps.
DC	....	10-375 amps.
Input Current (on 220V and at rated output)		
With Condensers	84 amps.	92 amps.
Without Condensers	108 amps.	108 amps.
Weight (Approx.)		
Net	630	760
Shipping, Domestic	680	820
Shipping, Export	800	950

INPUT POWER

Volts:	208, 220/440 or 220/550
Phase:	Single (or any one of 2 or 3)
Cycles:	60 or 50
Special Voltages:	220/380 and other single voltages available at slight extra charge

DIMENSIONS

	Height	Width	Depth
Machine, overall	44⅞"	26⅛"	28½"
Export crate	59⅝"	35¼"	37⅞"
Mounting Holes (centers, ⅝" x ⅞" slots)		28⅛"	14½"

* On AC inert gas applications this is reduced to 50% when using wave filter and to 35% without aid of wave filter.

LINCOLN ...USA

THE LINCOLN ELECTRIC COMPANY

The World's Largest Manufacturer of Arc Welding Equipment!

CLEVELAND 17, OHIO

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Now, with just one postcard, you can gather all the literature offered in the Journal. Just follow these simple steps for quick action:

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November, 1959

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5	30	55	80	105	130
6	31	56	81	106	131
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9	34	59	84	109	134
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22	47	72	97	122	147
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7	32	57	82	107	132
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9	34	59	84	109	134
10	35	60	85	110	135
11	36	61	86	111	136
12	37	62	87	112	137
13	38	63	88	113	138
14	39	64	89	114	139
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16	41	66	91	116	141
17	42	67	92	117	142
18	43	68	93	118	143
19	44	69	94	119	144
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WELDED CONTINUOUS FRAMES AND THEIR COMPONENTS
PROGRESS REPORT NO. 32

Corner Connections Loaded in Tension

Tests of the effect of combined tension and bending are made on square corner connections previously tested in compression

BY JOHN W. FISHER AND GEORGE C. DRISCOLL, JR.

ABSTRACT. A series of straight welded corner connections, having diagonal and half-depth vertical stiffeners, were tested in a manner which produced moments that tended to open the connection legs. This simulates a rather infrequent type of loading, which increases the possibility of weld fracture due to the stress conditions at the re-entrant corner.

Except as noted otherwise, these tests were carried out on specimens tested previously in compression, that is, with forces and moments tending to close the connection legs.

The results presented here show that the tension form of loading does not constitute a possible limitation on the application of plastic analysis to structural design. With proper welding procedures, the desirable strength, stiffness and rotation capacity can be realized.

Introduction

Purpose and Scope of Investigation

A series of tests was carried out at Lehigh University as part of a program on welded corner connections, a study which is a part of a general investigation of the plastic behavior of welded continuous frames and their components.

Earlier studies covered the testing of a number of corner connections of different designs, all connecting 8B13 members.[1] Later studies were made concerning the effect of size of member on connection behavior.[2]

In the phase being reported here, the tension behavior of knees is discussed. Some tension tests were conducted earlier on thirteen corner connections joining 8B13 members and the results were reported in Reference 3. This report will deal with tension tests of larger corner connections previously tested in compression for a series of tests to study a possible "size effect" and two 12WF36 corner connections which were taken from a simple portal frame.[4] One of the 12WF connections was in the "prime" or untested condition while the other was previously strained beyond the elastic limit in compression.

Under "compression loading" the forces acting on a knee tend to close it as in Fig. 1a. "Tension loading" refers to that condition in which the forces tend to open a joint as in Fig. 1b.

Common loadings on continuous frames require that the corner connections be subjected to combinations of bending moment and compressive thrust. Certain special cases require that the connections withstand bending moment and tensile forces rather than the normal bending moments and compressive forces that would occur under most loading conditions. These special cases would include buildings subjected to blast, flat roofs with light dead load and live loads but large lateral forces and crowns of gable roofs. A discussion of possible tension-type loadings is contained in Reference 3.

A few additional tension tests were desirable on larger specimens than previously studied to establish the behavior of connections when subjected to this type loading as a guide to design, especially since the possibility of weld failure is increased due to constraints which produce a triaxial state of stress.

Measurements made during the tests were used to determine whether the knee would meet the basic requirements for knees set forth in Reference 1. The requirements are the same for both tension and compression loading of knees in structures.

These requirements are:

(*a*) The knee must be capable of resisting at the corner the full

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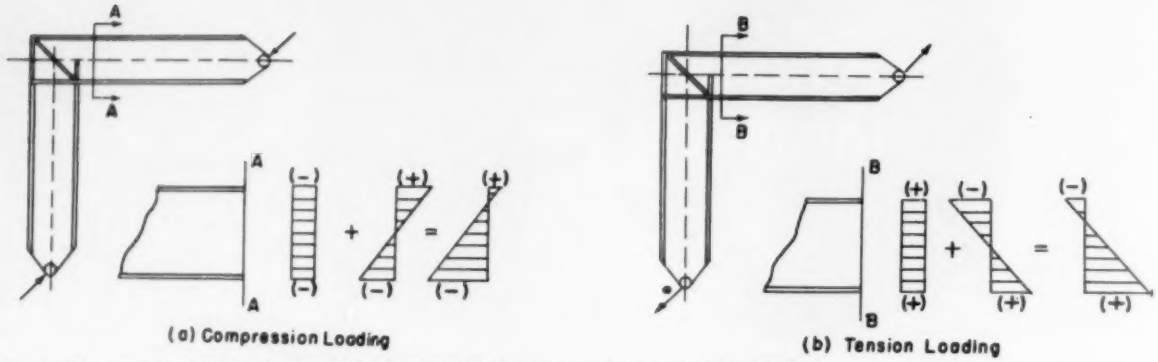


Fig. 1—Diagram showing elastic-stress distributions due to compression and tension loadings

plastic moment, M_p, of the rolled section joined.

(*b*) The stiffness should be at least as great as that of an equivalent length of the rolled section joined.

(*c*) The knee should have sufficient rotation capacity; that is, it should be capable of absorbing further rotations at near-maximum moments after reaching the plastic hinge condition.

(*d*) The knee should be economical to fabricate.

Tension at the re-entrant corner of the knee imposes a more severe requirement on the performance of the weld in the vicinity of that point because of the tri-axial stresses that are present. Hence, the interest of these tests is primarily on the possibility of weld failure and whether or not any such failures would limit the load or deformation capacity of welded connections subjected to tension loading.

Description of Test Specimens and Apparatus

Test Specimens

Each knee consisted of two identical members originally joined at right angles. Since all of the knees but one had been previously tested in compression, they were distorted somewhat from the earlier tests, having buckled previously, and were permanently deformed both locally and laterally. The 12WF36 "prime" connection, which was cut from a full-sized single-bay rectangular rigid frame, had a very small amount of permanent set remaining from local yielding during the frame test. However, this deformation was negligible because the moment in this knee was at all times below the yield moment during the frame test.[4] As is shown in Fig. 2, the end of the web of the column was joined to the lower flange of the beam. The inset to Fig. 2 shows a sketch of the weld detail at the re-entrant corner of a typical connection. A complete description of the test specimens is contained in Reference 2.

It was necessary to put extensions on the ends of the 12WF36 knees since they were cut from a frame tested earlier. These extensions were made from a 14WF30 rolled section (Fig. 3).

The members were all rolled from A-7 structural steel, and their physical properties were measured in conjunction with the earlier test programs in which they were used. The summary of coupon test results and the measured cross-sectional properties of the 12WF36

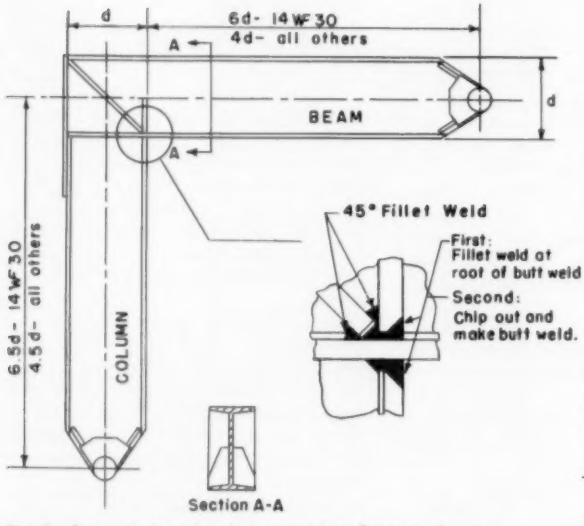


Fig. 2—General view showing geometry of connections and a typical weld detail at re-entrant corner

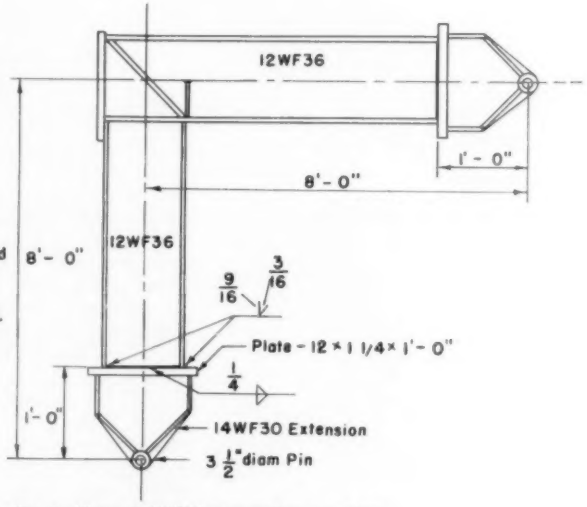


Fig. 3—View of 12WF36 connection showing extensions added for tension test

Table 1—Chemical Properties

Description	Heat no.	% C	Mn	P	S	Remarks
12WF36	...	0.18	0.65	0.014	0.038	A7–50T
14WF30	41K525	...	...	0.023	0.044	A7
24WF100	44D508	0.18	0.56	0.016	0.039	A7-52T
30WF108	44G451	0.20	0.60	0.01	0.030	A7-53T
36WF230	35D654	0.19	0.70	0.014	0.032	A7-52T

Fig. 4—Over-all view of 24WF100 corner connection in testing machine prior to tension test

members are given in Tables 1 and 2 of Reference 4. The same information for the 14WF30, 24-WF100, 30WF108 and 36WF230 members are given in Tables 1 and 2 of Reference 2. In general, these results indicate that the average yield strength of the coupons was from 35 to 40 ksi, and that no measured dimension varied by more than 6% from handbook values.

In Table 1 of this report, are listed the chemical properties of the steel used in the specimens. The chemistry is such that even with the thick flanges of the larger sections, it was considered appropriate to weld the connections without preheating or using special electrodes in accordance with the suggestions of Reference 5.

Loading System

In the connection tests, the knees were set up in an 800,000-lb screw-type testing machine in the position shown in Fig 4. The knees were set with legs at 45 deg with the horizontal, and concentrated loads were applied along the hypotenuse of the triangle. The effect of this loading was to cause bending moments which were maximum at the corner, plus equal shear and tensile forces.

Steel pins twelve inches long, welded perpendicular to the plane of the web, transmitted the load from plate links which were secured to each head of the machine by 6 in. pins. Figure 5 is a diagrammatic sketch of the links and specimen. These pins were able to rotate in the plane of the connection, thus a condition of zero moment existed at the points of load application. The end pins and web were stiffened by doubler plates and stiffeners, as shown in Fig 2, which were also designed to carry part of the end reaction to the flanges.

Lateral Support

Lateral support was provided for the 12WF36, 14WF30 and 24WF100 connections by a system of four tie rods attached to the inner and outer corners of the knees at the tips of the flanges. The tie rods were arranged so as to restrain the knees from any deflection except in a vertical plane. A description of the lateral support system is contained in Reference 2.

Since the connections were permanently deformed both locally and laterally during the previous compression tests, there was a tendency to induce large forces in the lateral support system as the connection tended to straighten out when the load was applied. This necessitated frequent adjustments in the lateral support system. Since the magnitude of the lateral forces so measured was meaningless, it was decided not to provide lateral support for the 30WF108 and 36WF230 knees.

Rotation Measurements

Rotation indicators of the types indicated in Figs. 6 and 7 were used to determine the rotation of the knee. Seven indicators of the type shown in Fig. 6 were used on the 12WF36 connections: one across the knee and three across each leg. The other connections used five rotation indicators of the type shown in Fig. 7: one across the

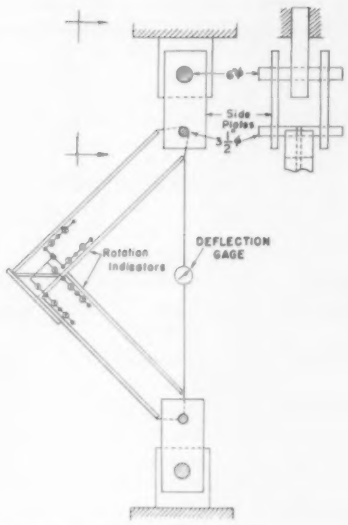


Fig. 5—Schematic drawing of tension-test setup

Fig. 6—Rotation indicators on 14WF30 corner connection. One-inch angles were used to support dial gages

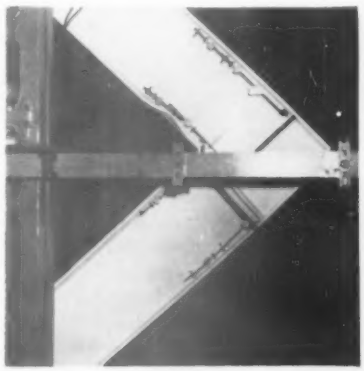
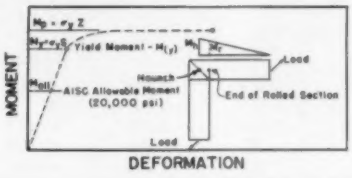


Fig. 7—Rotation indicators on 36WF230 corner connection. One-half inch diameter rods were used to support dial gages

Table 2—Summary of Theoretical Moments



Section	Basis of calculation	Moments in Kip-Inches: Elastic range M_y (parameter)	Elastic range: M allowable[a] (AISC)	Elastic range: $M_{h(y)}$[a]	Elastic range: $M_{r(y)}$[a]	Plastic range: M_p (parameter)	Plastic range: $M_{h(p)}$[a]	Plastic range: M_{pc}
12WF36	Measured[b]	1,700	982	1,730	1,620	1,880	2,000	1,871
	Handbook[c]	1,515	875	1,540	1,445	1,698	1,800	1,689
14WF30	Measured	1,488	757	1,530	1,412	1,734	1,870	1,725
	Handbook	1,380	830	1,482	1,370	1,553	1,672	1,544
24WF100	Measured	8,450	4,440	8,750	7,775	9,750	10,820	9,619
	Handbook	8,210	4,590	8,500	7,580	9,170	10,160	9,027
30WF108	Measured	10,100	5,360	10,500	9,345	11,601	12,930	11,500
	Handbook	9,870	5,540	10,260	9,140	11,400	12,700	11,300
36WF230	Measured	29,450	15,100	30,550	27,150	34,810	38,650	34,380
	Handbook	27,600	15,400	28,550	25,400	31,100	34,400	30,650

[a] M_{all}, M_h and M_r were calculated considering the effect of axial load.
[b] "Measured" quantities calculated using measured dimensions and coupon stresses.
[c] "Handbook" quantities calculated using AISC handbook dimensions and implied yield stresses (33 ksi).

knee and two across each leg. A detailed description of the development and use of this type rotation indicator is given in Reference 6.

Deflection Measurements

The relative deflection of the ends of the legs was measured by a single dial indicator, attached to a rod which spanned the hypotenuse of the triangle formed by the legs of the knee (see Fig. 5). The plunger of the dial was set in a punch mark placed directly in line with the pin of the lower leg of the knee.

Changes in the average length of the moment arm were measured by means of a "mirror gage." This consisted of a plumb bob attached by a wire or string to the outside corner of the knee and suspended in a bucket of water placed at the base of the testing machine, thus preventing excessive swaying. A 0.01-in. scale equipped with a mirror was used to measure the horizontal displacement of the string or wire.

Test Procedure

In the conducting of each test, four phases of the test required slightly different procedures. These phases were:

1. Initial adjustment of the test apparatus and taking of zero reading of the instrumentation.
2. Elastic-range loading, with load and deformation readings controlled by a load criterion.
3. Plastic-range loading, with load and deformation readings controlled by a deflection criterion.
4. Plastic-range loading, after maximum load, with a minimum of deformation readings.

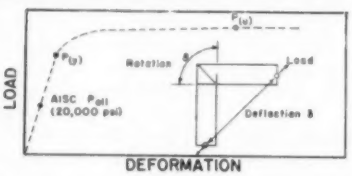
A complete description of each of the individual phases is included in Reference 2 and is directly applicable to this report. It was necessary to watch for the development of a possible weld fracture in addition to the points outlined in the test phases.

Analysis and Design of Square Knees

Theoretical Analysis

The theoretical analysis of the

Table 3—Summary of Theoretical Loads and Deformations



Section	Basis for calculation	Loads: P_{all} (AISC) kips	Loads: P_y kips	Loads: P_u kips	Deformations: δ_y in	Deformations: θ_y radians	Deformations: θ_{Ty} radians
12WF36	Measured	15.45	25.5	29.4	1.02	0.00327	0.01249
	Handbook	13.80	22.75	26.5	0.855	0.00279	.....
14WF30	Measured	12.70	23.7	29.0	0.819	0.00378	0.00904
	Handbook	13.94	23.0	26.0	0.741	0.00303	..
24FW100	Measured	65.5	114.3	141.5	0.626	0.00306	0.00778
	Handbook	67.5	111.4	133.0	0.584	0.00269	...
30WF108	Measured	63.2	110	135.5	0.738	0.00262	0.00428
	Handbook	65.1	107.4	133.0	0.683	0.00249	...
36WF230	Measured	148.5	267	338	0.934	0.00280	0.00775
	Handbook	151.0	249	301	0.856	0.00262	...

Table 4—Comparison of Moments at Which Local Buckling Occurred, Kip-Inches

	Connection				
Type load	12WF36	14WF30	24WF100	30WF108	36WF230
Compression	2153	1690	10,418	Not observed	35,641
Tension	2380	1980	12,992	14,324	Weld fracture prior to local buckling at a moment of 41,300

connections reported herein was presented in earlier reports.[2,7] There is no significant difference between the theoretical analysis for either tension or compression loading upon a knee. Hence, much of the procedure and theory reported in Reference 2 is directly applicable to this companion report. The results that apply to both reports are summarized in Tables 2 and 3.

The only characteristic of behavior that is changed, except for the possibility of weld fracture, is local buckling. Local buckling of the compression flange is delayed during the tension test in comparison with the compression test. Figure 1 indicates the reason why local buckling is more critical for compression than for tension. Under compression loads, the local buckle would occur at lower moments because the compression flexural strains are additive to the direct strains resulting from the axial compressive force. However, under tension loading, the compression flexural strain is reduced by the superimposed direct-tensile strains. Therefore, local buckling occurs at higher moments when the connection is subjected to "tension" loadings. Table 4 shows the moments at which local buckling occurred for both tension and compression tests.

Design of the Knees

The detailed procedure for the design and fabrication of the knees is presented in References 2 and 7. The stiffening required to prevent excessive distortion, the design of the welds, and the welding sequence that was used in order minimize distortion and prevent weld cracking are outlined and discussed in Reference 2. Reference 7 contains a sample analysis and design of the 24WF100 connection and shows the development of the required stiffening.

Test Results

The results of the experimental investigation and their correlation with the data obtained from the compression test are next presented. The discussion follows.

Moment-deflection Results

In Fig. 8 the nondimensional curves of moment vs. deflection are given for the connections tested in this series. They are compared with the curves obtained from the earlier compression tests. The values of M_y and δ_y are computed from the theoretical considerations as presented in Reference 2, using coupon data and actual cross-section measurements. The haunch moment, M_h, is computed at the intersection of the neutral lines of the adjoining members of the connection. In all experimental curves, the moment has been corrected for the measured increase or decrease in moment arm due to the deflection between end pins. Numerical results of the nondimensionalized curves can be obtained from Tables 2 and 3.

Moment-rotation Results

In Fig. 9, the nondimensionalized curves of moment vs. rotation are presented. Each curve compares the results obtained from the tension test with those obtained from the

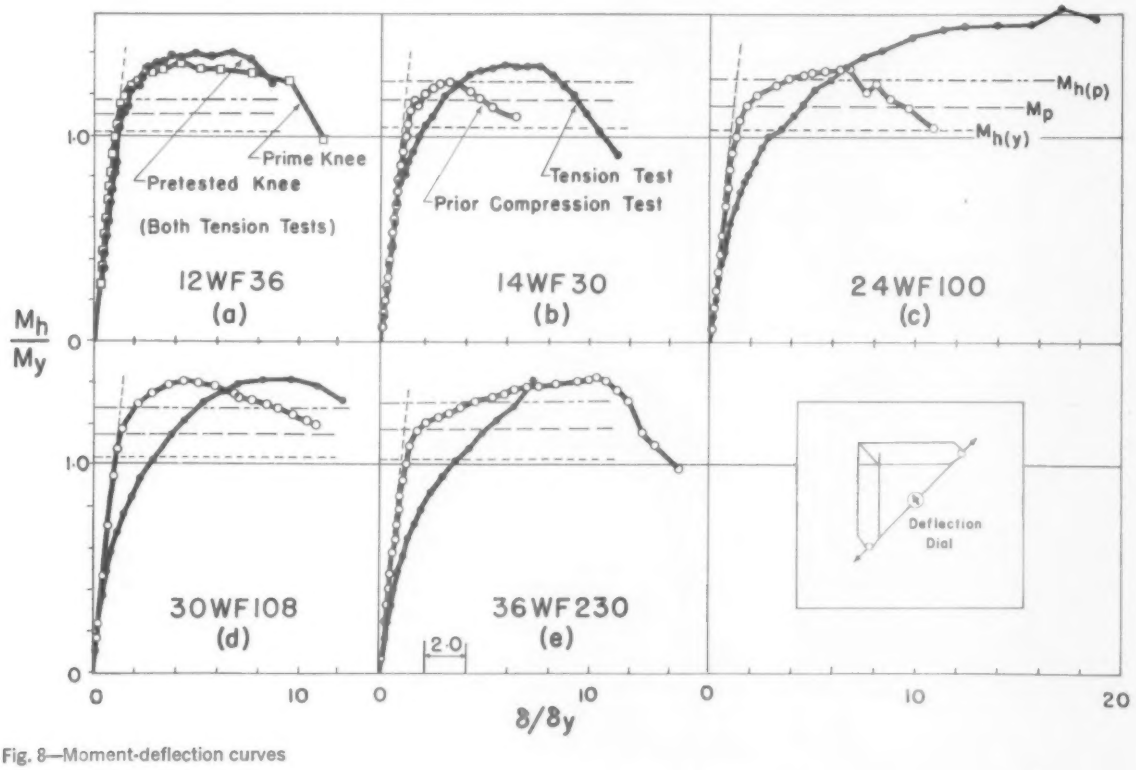


Fig. 8—Moment-deflection curves

compression test. θ_T is the total rotation experienced by the connection in the vicinity of the junction of column and beam. It includes the rotation of the legs over the portion to which the rotation indicators are attached.

It should be pointed out that erratic behavior of the elastic portion of the moment-rotation results must be expected for the tension tests. This is primarily due to the buckled configuration of the connection resulting from the prior compression tests. As load was applied, the connections tended to align and straighten out causing the uncertain behavior in the rotation indicators.

Strength and Rigidity of the Connections

Figure 8 shows the strength of connections subjected to tension loads. Table 2 presents a summary of the numerical values of the theoretical strength of the connections. The maximum moment values shown in the nondimensionalized curves can be obtained with the aid of Table 2.

Figure 9 indicates the rigidity of the connections tested in tension. The earlier nonlinear behavior exhibited at lower loads than in the previous compression tests is primarily due to the Bauschinger effect. (A phenomenon that occurs when a specimen is loaded in tension or compression above the proportional limit and then reloaded in the opposite direction. It is observed that yielding of the specimen as a whole occurs at a much reduced stress.) A more comprehensive explanation of the effect can be found in Reference 8.

Discussion of Test Results

Before beginning discussion of the individual test results, the significance of the moments M_p and $M_{h(p)}$ will be interpreted for the general case.

In the analysis of a flat-roofed rigid frame, the ultimate load would be based on the assumption that the moment at the intersection of the beam and column centerlines was M_p. This assumption neglects the fact that the column and beam sections have depth. Any test result in which the moment at the haunch M_h equals or exceeds M_p indicates a connection adequate to be used in a rigid frame.

Observation of previous tests has shown that, in square corner connections, the plastic hinge will ordinarily form in the rolled section outside the corner.[1, 2, 3] Therefore, the moment, M_r, at the edge of the rolled section may reach M_p (corrected for axial load) and the moment, M_h, at the haunch may reach a greater value $M_{h(p)}$, depending on the moment gradient (see sketch in Table 2). This greater moment $M_{h(p)}$ is ordinarily reached without requiring additions to the design or fabrication procedure. It is of interest to the experimenter to compare the maximum haunch moment achieved in a test with a predicted value for $M_{h(p)}$ merely to gage the accuracy with which such predictions may be made. Let it remain clear, however, that reaching M_p is all that need be required of a haunch to satisfy a design standard for strength.

Of course, it is not inconceivable that a designer might elect to reevaluate a design on the basis of this small increase in moment supplied and reduce the size of sections used. However, this procedure is not recommended because it increases the complexity of the analysis. It is probably more practical to have this small reserve of strength available as an additional safety measure against instability.

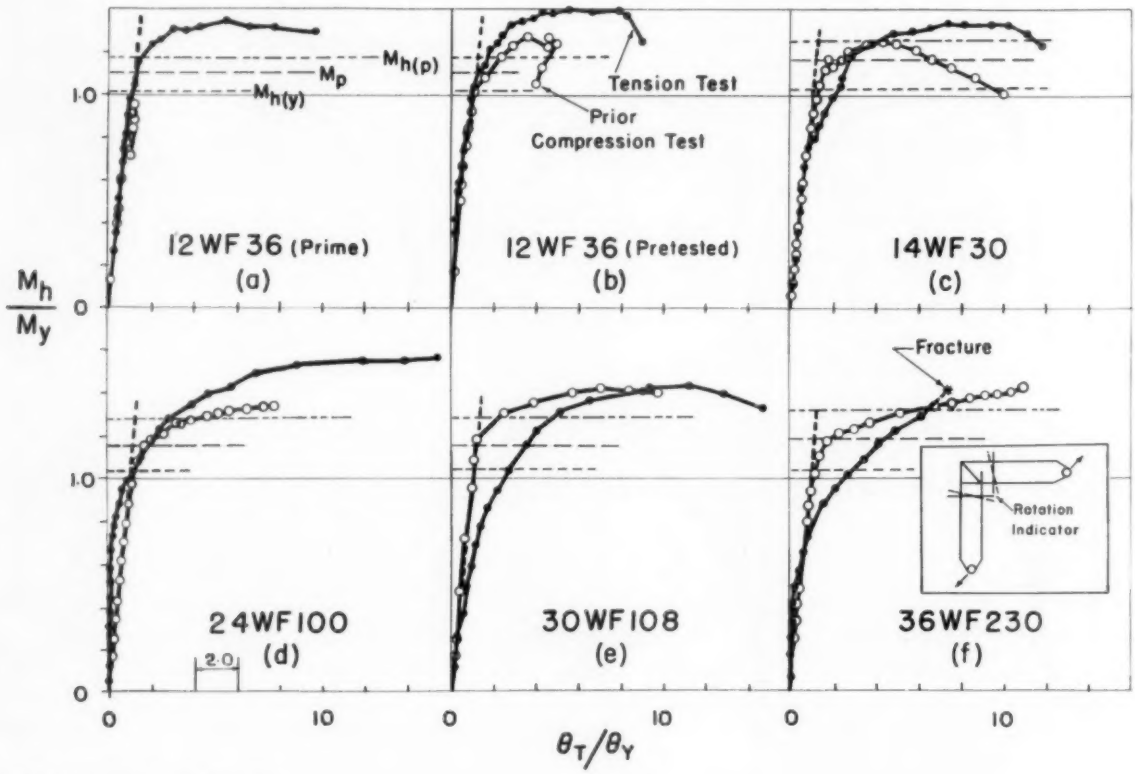


Fig. 9—Moment-rotation curves

Discussion of Each Connection Tested

12WF36 (Prime) (242T1). In Fig. 8a is shown the moment-deflection curve of the prime knee from the tension test. Deflection was not measured during the prior compression of the 12WF36 knees because their prior test was in the form of a flat-roofed portal frame. The curve shows that the connection followed very closely the predicted theoretical curve to yield. The ultimate moment was about 35% greater than the theoretical yield moment. The connection was capable of carrying a moment equal to or greater than the theoretical plastic moment through a deflection of ten times the predicted theoretical yield deflection. In Fig. 9a, a comparison is made between the moment-rotation curves for the compression and tension test of the prime connection. It can be noted that very little difference exists between the two curves and the tension curve followed very closely the predicted theoretical curve. The connection was able to sustain large rotations at moments greater than the plastic moment. There is little if any variation in the elastic range that can be attributed to the Bauschinger effect since the connection was not loaded beyond the elastic limit during the compression test.

Failure was brought about primarily by lateral-torsional buckling, although some local buckling was present. There were no weld cracks observed at any time during the test.

12WF36 (Pretested) (242T2). This knee was deformed from the prior frame test and a limited amount of local and lateral deformation remained. From the moment-deflection curve (Fig. 8a), the effect of the prior compression test shows little if any influence on the elastic behavior of the connection. It can be observed from Fig. 9b that the connection was not required to sustain as large an amount of deformation during the compression test as in some of the larger connection tests. Hence, it is probable that this would not influence the elastic behavior as in the larger size connections, and the Bauschinger effect might not be as pronounced for this connection.

Figure 9b shows a comparison between the moment-rotation curves of the tension and compression tests. Note that very little deviation is evident in the elastic portion of the curves. The connection was able to sustain a much greater rotation under the tension loading at moments greater than the plastic moment since local and lateral buckling was delayed.

The connection was able to develop an ultimate moment which was 40% greater than the theoretical yield moment. This ultimate moment was about 15% higher than the ultimate moment of the prior compression test. Failure was again brought about by lateral-torsional buckling similar to that of the prime knee.

14WF30 (T104). In Fig. 8b, the moment-deflection curves for both the tension and compression tests are shown just above the results for the 12WF36. There was very close agreement between the two curves until about 75% of the theoretical yield was reached. Then the curve of the tension test started deviating quite rapidly due to the effect of prior loading.

The apparent deviation did not prevent the connection from developing an ultimate moment which was about 10% greater than the ultimate moment obtained during the compression test.

In Fig. 9c, the moment-rotation curves are shown. Again there is a slight discrepancy during the elastic portion of the tension curve due to the configuration of the knee prior to testing. The knee was able to sustain much larger rotations when tested in tension at moments equal to or greater than the plastic moment.

Failure of the connection was brought about primarily by lateral-torsional buckling. During the compression test of this knee, failure was primarily from local buckling. The reason for this difference in failure mode was mentioned in the section on "Theoretical Analysis."

24WF100 (T41). A comparison of the moment-deflection curves for the tension and compression tests is shown in Fig. 8c. The knee started deviating from the theoretical curve at very low loads. The ultimate moment was about 25% higher than the ultimate moment of the compression test.

There is a marked discrepancy of the moment-rotation curve for the tension test shown in Fig. 9d. It shows the experimental rotation being considerably less than predicted until the yield moment is reached. This does not coincide with the results obtained in Fig. 8c. This discrepancy is probably due to the lateral and local deformation that remained from the previous compression test. As the connection tended to straighten,

Fig. 10—Lateral buckling of 24WF100 corner connection

Fig. 11—Lateral buckling of 30WF108 corner connection

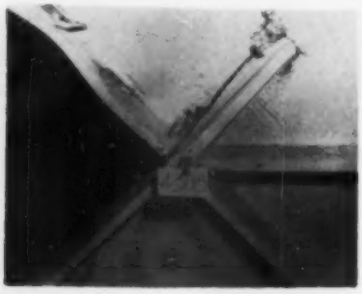


Fig. 12a—A fracture began at the inner flange of the beam in the 36WF230 connection and progressed about halfway into the web.

Fig. 12b—The fracture of the beam flange occurred just outside a butt weld connecting the end of the column flange to the surface of the beam flange

Fig. 13a—A close-up of the fracture surface in the 36WF231 connection shows the brittle-fracture pattern. View facing toward beam

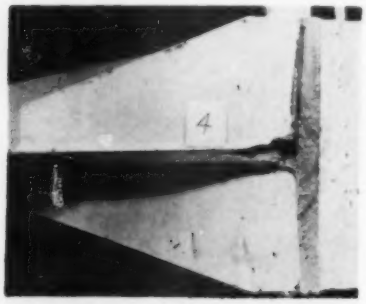


Fig. 13b—Fracture surface facing toward half-depth vertical stiffener. To the left is a short length of oxygen-cut surface made to allow parts to be separated for photographing

erratic behavior occurred in the rotation indicators. At times they indicated rotation in the sense opposite to that expected, presumably due to the lateral deformation.

Once the load had passed the predicted yield, the connection behaved as expected; it sustained a moment greater than or equal to the plastic moment through a rotation of approximately twice that obtained during the compression test.

Eventually, after the connection had rotated far beyond any value that would be required in plastic design, lateral-torsional buckling occurred (Fig. 10). No weld cracks were observed during the test.

30WF108 (T42). The moment-deflection results of the tension and compression tests are compared in Fig. 8d. The departure from linearity started at about 40% of the theoretical yield moment. The ultimate moment attained by the knee is very nearly the same for both the tension and compression tests. The early departure from linearity had no adverse effect upon the strength of the connection.

In Fig. 9e the moment-rotation results are compared for the tension and compression test. The departure from linearity is evident from the onset of the test. The connection was able to sustain rotation at moments equal to or greater than the plastic moment. This rotation exceeded the rotation obtained during the compression test by about 30%. Final failure of the knee was primarily due to lateral-torsional buckling.

36WF230 (T43). This was the largest connection tested in this series. In Fig. 8e the moment-deflection results are presented for both the compression and tension test. Again, the tension test shows greater flexibility. Figure 8e shows that the connection exceeded the predicted maximum moment by about 8% and the plastic hinge moment by about 20%.

After the connection had deflected an amount equal to about 8 times the predicted yield deflection, a fracture occurred. The moment reached was slightly below the ultimate moment which had been reached in compression, but was still 18.6% greater than that required by a design which incorporates an overload factor of 1.85. The deflection sustained in the tension test was about 60% of the deflection in the compression test.

The moment-rotation results are shown in Fig. 9f. As with the 24WF100 connection, the measured rotation in the elastic range was less than the theoretical predicted value. However, at about 60% of the predicted yield the knee showed a rather rapid departure from linearity. The connection was able to maintain moments equal to or greater than the plastic moment through a rotation of five times the predicted yield rotation. Additional deformation was not possible due to failure of the beam flange adjacent to the butt weld at the re-entrant corner. The failure of the knee was due to brittle fracture occurring in the beam flange at the re-entrant corner of the inside flanges. The flange which fractured was actually the flange which was continuous through the whole connection, and not the flange which was butt welded. The crack propagated to the midpoint of the web of the beam, and the load-carrying capacity of the connection immediately dropped.

Connections subjected to tension-type loadings are seldom encountered in practice. When they do exist, they require much less deformation capacity than those subjected to compression-type loading. Therefore, no limitation to plastic design is implied from the fracture. Eventually a component must fail, and due to the geometry and type of loading it happened that this one fractured instead of failing in the usual buckling mode.

Figures 12 and 13 are photographs showing the extent of fracture in the beam web and the fracture surfaces. The main body of the fracture is typically "brittle" as evidenced by the small lateral contraction at fracture, the absence of shear lip and the cleavage appearance of the fractured surface.

The weld itself had sufficient strength to force the failure to occur adjacent to it. Such a fracture in thick material with heavy welds is not unexpected in view of the large amount of prior compressive strain which exhausted much of the available ductility. The fact that under reversed tension loading the connection could sustain about 8 times the predicted yield deflection is a further verification of plastic theory.

Performance of Welds

In five of the six connections tested, there were no cracks or weld failures observed. Only the 36-WF230 knee exhibited a fracture which brought about failure of the connection. However, it is clear from Figs. 8e and 9f that the connection was able to sustain some

Table 5—Chemical Analysis of Steel for 36WF230 Connection

	Ladle analysis, %	Core analysis, %
C	0.19	0.23
Mn	0.70	0.68
P	0.014	0.013
S	0.032	0.035
Si	[a]	0.11

[a] Not recorded.

plastic deformation prior to this failure.

As indicated in Reference 2, it was not considered necessary to use a preheat or low-hydrogen electrode on any of the connections fabricated. According to Reference 9, with carbon less than or equal to 0.25% and the thickness being welded over one inch but less than two inches, it is generally recommended that some control be made over the heat input and that a low-hydrogen electrode or preheat be used in order to prevent a brittle-type failure. This was not done on the 36WF230 connection which had an average flange thickness of 1 1/4 in. When this connection was tested in compression, satisfactory behavior was obtained and no cracking was observed. However, when tested under a tension-type loading, a brittle-type failure did occur. Where extremes in the service temperature of a building are anticipated, it would be necessary to take precautions in order to prevent any possibility of brittle failure.

The chemical properties of the ladle analysis and an analysis made on a core specimen after the fracture occurred are shown in Table 5. It can be noted that the carbon content is 0.04% greater in the core specimen. However, as pointed out in Reference 5, there may be as much as 0.04% more carbon in the steel as delivered as compared to the ladle analysis.

It is interesting to note that the recommendations of References 5, 9 and 10 put the welding of the 36WF230 connection in a borderline category. That is, References 9 and 10 recommend the use of preheat or low-hydrogen electrodes, and Reference 5 does not. At the same time, the test results must be interpreted as also being in a borderline category. The connection reached its ultimate load and withstood sufficient deformation to allow it to do its job satisfactorily.

Problems concerning the metallurgical aspects of welding steel thickness greater than one inch are beyond the scope of this report, but are covered in References 5, 9 and 10. The important point to note is that the connection welded according to the most liberal recommendations of these authoritative sources (Reference 5), performed satisfactorily.

Summary and Conclusions

The following observations can be made from the results of this study of square knees under "tension loading," in which the re-entrant corner of the knee is in tension.

1. All connections reached the predicted plastic moment and exceeded it by an amount that varied from 4 to 33% (Figs. 8 and 9).

2. Local buckling occurred at higher moments in the tension test than it did in the previous compression test (Table 4).

3. The ultimate moments reached during the tension tests were higher than the ultimate moments that were obtained during the prior compression test, except for the 30WF108 and 36WF230 connections. The ultimate moment attained by the 30WF108 connection was approximately the same in both tests. The ultimate moment of the 36WF230 connection was about the same as that of the prior compression test when failure of the beam occurred (Figs. 8 and 9).

4. Sufficient rotation was attained at moments equal to or greater than the plastic moment to have allowed redistribution of moments had the knee been part of an indeterminate structure (Fig. 9). Since the plastic hinge would form last at the tension corner, very little rotation is required at that point.

5. All connections but the 36WF230 knee failed by lateral torsional buckling with some local buckling in the web and flanges. The 36WF230 failed due to fracture of the flange adjacent to the butt weld at the re-entrant corner (Figs. 10 through 13).

6. With proper welding procedure and with careful inspection of welding, the development of plastic hinges in large-size members without fracture of the welds may be assured. These connections are able to absorb sufficient rotation at near-maximum moment after reaching the plastic-hinge condition.

7. The prior loading and resulting plastic deformation from the previous "size-effect" studies cause some erratic behavior to occur in the elastic and initial plastic portions of the tests for tension study. Such things as erratic rotation, deflection and lateral support behavior may be attributed to the prior loading. Hence, the results are probably conservative. Prime specimens would have performed better.

8. In one instance of thick material, the use of low-hydrogen electrodes or preheat which some welding engineers would have prescribed was omitted. Despite this, the test results show that plastic design of rigid frames would be no more limited by fracture than would a comparable elastic design. In most structures the hinge subjected to the tension-type load would be the last to form and would not require the additional rotation needed by the other hinges. Thus, the 36WF230 which did attain the plastic moment prior to fracture would be satisfactory.

Acknowledgments

This report has been prepared as a result of research carried out at Lehigh University in the Fritz Engineering Laboratory. William J. Eney is Director of the Laboratory and Head of the Department of Civil Engineering. The work was done as part of a larger program on Welded Continuous Frames and Their Components directed by Lynn S. Beedle. F. W. Schutz supervised the planning and execution of the test program. Technical guidance and supervision for this project was furnished by the Lehigh Project Subcommittee of the Structural Steel Committee, Welding Research Council. T. R. Higgins is chairman of the Lehigh Project Subcommittee. The authors wish to express their sincere appreciation to the Lehigh Project Subcommittee for valuable suggestions received.

Thanks are also extended to Kenneth R. Harpel, foreman, and the Laboratory staff of technicians, who erected the specimens and offered helpful suggestions in regard to test apparatus. Bryan C. Chapman assisted in the tests. The results of the tension tests on the 12WF36 connections were supplied by R. B Madison and T. E. Gunn. The assistance furnished by members of the Fritz Laboratory staff in the preparation of this manuscript is gratefully acknowledged.

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Nomenclature and Terminology

d = depth of section

M_{all} = allowable moment (as at 20 ksi under AISC Spec.)

M_h = "haunch" moment. Moment at intersection of beam and column centerlines. (subscript "y" refers to moment when flexure yield is reached at junction of rolled beam and corner; subscript "p" refers to moment when plastic hinge moment is reached at junction of rolled beam and corner.)

M_p = "Hinge" value of full plastic moment; the ultimate moment that can be reached at a section according to the simple plastic theory = $\sigma_y Z$

M_{pc} = plastic hinge moment modified to include the effect of axial compression

M_r = moment in a member at junction of rolled beam and corner

M_y = moment at which the yield point stress is reached in the rolled section = $\sigma_{yL(f)} S$

P = load

P_{all} = allowable load (as at 20 ksi under AISC Spec.)

$P_{(y)}$ = load when yield stress is first reached in the extreme fibers of rolled section.

$P_{(u)}$ = ultimate load (theoretical)

S = section modulus of beam

t_s = stiffner thickness

w_r = required web thickness

Z = plastic modulus; the combined statical moments of the cross-sectional areas above and below the neutral axis.

δ_y = deflection; (subscript "y" refers to deflection at yield)

θ = rotation; (subscript "T" refers to total rotation within a rotation indicator, "y" refers to rotation of knee at yield)

σ = direct stress (bending)

σ_{yL} = lower yield point stress (subscript "f" refers to flange)

τ = shear stress (subscript "y" refers to shearing yield stress)

British Welding Research Association Publishing Cover-to-Cover Translations of Another Russian Monthly Welding Journal

The British Welding Research Assn. which, earlier this year, began publication of cover-to-cover translations of the Russian monthly journal *Automatic Welding* is now going ahead with a second journal. It is the monthly *Svarochnoe Proizvodstvo* (*Welding Production*), covering research and welding practice. These translations are checked for technical accuracy by experts on the Association's staff.

The translations form part of a scheme sponsored by the British Department of Scientific and Industrial Research, in liaison with U. S. authorities, to make information on Russian welding progress freely available in western countries. Since it is the aim of research organizations on both sides of the Atlantic to avoid duplication of this type of work, these will be the only English versions of the two principal Russian welding journals published.

These are some of the articles appearing in the first four issues of *Welding Production*.

Research: Techniques for welding the reactive metals; distribution of heat flow between plates in arc-welded tee-joints; new austenitic electrodes for welding 13Cr–18Ni–2W + B steel; resistance welding of rails.

Welding Practice: Reuse of slag crust in automatic welding; tube oxygen-cutting machine; new torches for hand argon-arc welding; quality control of spot and seam welding.

Annual prepaid subscription will be $15 U. S. post free. Nine issues only will be available in 1959 at the reduced subscription of $12. U. S. Subscriptions should be sent to: British Welding Research Assn., 29 Park Crescent, London, W. 1., England.

Effect of Microstructure on Notch Toughness—Part IV

Microstructure and fracture morphology investigation of plain-carbon and alloy ferrites is carried out to determine relationship to notch toughness

BY E. H. KOTTCAMP, JR. AND R. D. STOUT

Introduction

The present paper is part of a series of investigations being conducted at Lehigh University to determine the effect of microstructural and compositional variables on the notch toughness of low-carbon steels used in welded construction.

Recently Gross and Stout[1] reported evidence to indicate that the ferrite phase of a structural steel was the controlling microconstituent in influencing the notch toughness of this material. Heat treatments designed to vary the pearlite hardness and spacing while maintaining a constant ferrite-grain size resulted in specimens with quite similar transition temperatures. The relationship between ferrite-grain size and transition temperature obtained was in agreement with that observed by Hodge, *et al.*,[2] in a study of low-carbon irons.

An investigation of the origin of brittle fracture in a 1025 steel led Danko and Stout[3] to conclude that cleavage failure was initiated at ferrite-pearlite interfaces, at the ferrite grain boundaries and possibly at mechanical twin boundaries within the ferrite itself.

The results of these and other investigations suggest the importance of the ferrite phase in determining the notch toughness of low-carbon steels.

Because low-carbon structural steels have a predominantly ferritic microstructure, a closer study of the ferrite phase seemed desirable for a better understanding of the behavior of these materials. In order to approximate the ferrite present in commercial steels a series of aluminum-killed carbon and alloy ferrites were obtained. The immediate purpose of this work was to determine the effects of alloying elements, ferrite-grain size, substructure configuration and numerous subcritical heat treatments on the notch toughness of ferrite. In addition, observations of microcracking were conducted to locate the region or regions of the microstructure responsible for initiation of brittle-cleavage failure. The objective of this series of investigations is to assess the influence of each of the microstructural constituents present in a steel and to develop, if possible, the parameters relating microstructure and notch toughness. These factors are relevant to the wide range of microstructures produced by the thermal cycles of welding.

Experimental Procedure

The chemical compositions of the materials employed are included in Table 1. Charpy V-notch specimen blanks were cut from hot-rolled $^1/_2$-in. square bar stock and normalized at 1750° F for 1 hr before imposing the desired heat treatments. Following final heat treatment, the Charpy blanks were machined to standard specimen dimensions.

To determine the influence of the ferrite-grain sizes encountered in welded steels on notch toughness, series of Charpy specimens were austenitized at various temperatures and cooled in still air or in the furnace. A listing of the heat treatments used and the grain sizes which were developed is shown in Table 2. The ASTM grain size determinations were made by lineal analysis as described in an earlier paper.[1]

Subcritical reheating treatments were employed to determine how the materials would respond to prolonged exposure at these temperatures and to various methods of cooling from them. It has occasionally been observed that the subcritical temperatures used in stress relieving result in a loss of notch toughness; hence, it is imperative that the effects of such heating procedures on the toughness of the ferrites be understood. In order to make certain that the lower critical temperatures of the manganese and nickel ferrites were not exceeded, a 1200° F limit was placed on the reheating temperatures used for these materials. Specimens were machined and tested within 48 hours of final heat treatment in an effort to standardize the effects of possible quench aging.

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Paper presented at the AWS National Fall Meeting held in Detroit, Mich., Sept. 28 to Oct. 1, 1959.

Table I—Chemical Compositions of the Ferrites

Ferrite	Element by weight, % C	Mn[a]	P	S	Si[a]	Ni[a]	Cr[a]	Mo[a]	Acid Al	Total Al
Carbon	0.021	0.36	0.016	0.010	0.24	...	...	...	0.042	0.049
Nickel	0.019	0.40	0.020	0.010	0.23	3.25	0.03	0.01	0.013	0.017
Manganese	0.015	1.52	0.018	0.010	0.38	0.05	0.03	0.01	0.023	0.035
Molybdenum	0.013	0.41	0.012	0.010	0.26	...	...	0.55	0.022	0.038
Chromium	0.024	0.40	0.010	0.010	0.24	0.05	1.08	0.01	0.024	0.034

[a] Spectroscopic analysis.

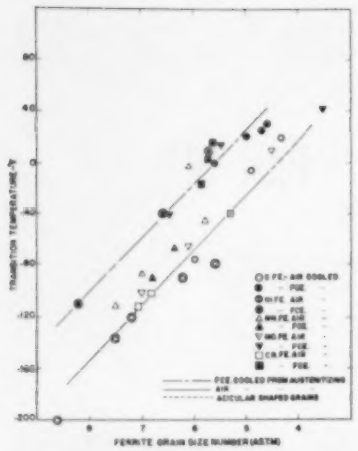


Fig. 1—Effect of ferrite grain size on the Charpy V-notch transition temperature

Table 2—ASTM Grain-Size Numbers of Carbon and Alloy Ferrites After Heat Treatment

Ferrite	Austenitizing temperature, ° F	Grain size after Furnace cooling	Grain size after Air cooling
Carbon	1700	5.5	...
	1900	5.0	6.0
	2000	4.7	5.7
	2100	4.6	5.3
	2150	...	4.9
	2250	...	4.3[a]
Nickel	1700	8.2	8.6
	1900	6.6	7.2
	2100	5.7	6.2
	2250	...	5.6
Manganese	1700	6.8	7.5
	1850	6.4	7.0
	2000	5.8	6.1
Molybdenum	1750	6.5	7.0
	1950	5.5	6.1
	2100	3.5	4.5[a]
Chromium	1750	5.9	6.9
	1800	5.7	7.1
	1950	5.6	6.0

[a] Acicular shaped grains.

Fracture study specimens were prepared by nickel plating the fracture surface of Charpy specimens and polishing a section perpendicular to the plated surface. This technique did not prove entirely satisfactory for microcrack study since the completely fractured specimens usually had only primary or well-developed secondary cleavage paths present. Because of the sharp decrease in energy encountered at the transition temperatures of these materials, a more carefully controlled technique had to be developed to produce microcracks which could be arrested before complete failure. One operation, which proved successful, was to load a standard Charpy V-notch specimen as a simple beam with a sharp tup mounted on a tension machine, placing the V-notch on the tension side. By locating a pointed metal probe fastened to a phonograph pickup behind the notch, the initial microcracks could be detected by audible signals. When the first cracking was heard, the specimens were unloaded, sectioned and polished until the microcracks were visible. Tests of this type were conducted at temperatures well below the transition temperatures obtained in the standard impact machine.

Results and Discussion

Impact-test Results

The results of the effect of ferrite-grain size on the notch toughness of the various ferrites are shown in Fig. 1. The transition temperatures reported are those temperatures at which a precipitous drop in energy absorption occurred, typical of very low-carbon irons.

From the data of Fig. 1, it is apparent that, while the general slope of the curve is in agreement with the 30° F per grain size number reported by Hodge, *et al.*,[2] a substantial displacement was observed between the specimens air cooled and those furnace cooled from the austenitizing temperature. Thus grain size, although having a predominant role in determining notch toughness, was not the sole factor controlling notched-bar behavior. Specimens of identical grain sizes developed by furnace and air cooling from appropriately chosen austenitizing temperatures, failed to produce similar transition temperatures when tested. Another observation from Fig. 1 is the slight increase in transition temperature over that otherwise expected due to the presence of acicular-shaped ferrite grains. An analogous behavior has been reported for Ti.[4] Since ferrite grains of an acicular configuration are commonly produced as a result of welding, such behavior is of particular

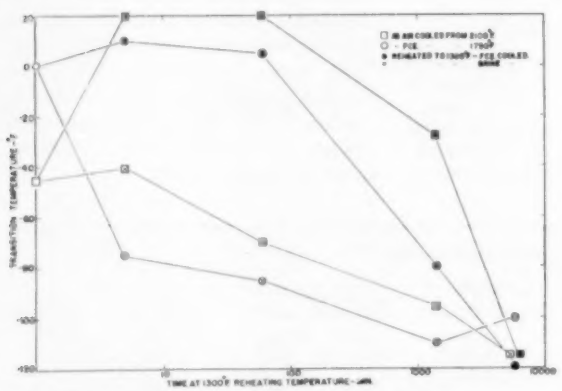


Fig. 2—Plain-carbon ferrite—Effect of subcritical heat treatment on the as-cooled transition temperatures. A.S.T.M. grain size No. 5.5

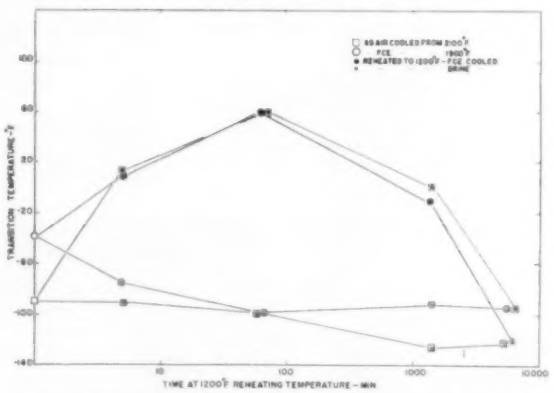


Fig. 3—Nickel ferrite—Effect of subcritical heat treatment on the as-cooled transition temperatures. A.S.T.M. grain size No. 6.4

interest in this field.

Subcritical heating experiments yielded the results shown in Figs. 2 through 6. The reheating temperatures selected represent temperatures higher than those normally used for stress relieving. The reasons for their selection will become evident as the discussion progresses. Series of each of the materials were initially air cooled and furnace cooled from temperatures chosen to provide the same final ferrite grain size. It is apparent from these figures that some degree of embrittlement occurred in the plain carbon, molybdenum and nickel ferrites after relatively short holding times followed by furnace cooling. Severe embrittlement was not encountered in the manganese and chromium ferrites for the exposure times studied. It is interesting to note that while the carbon, molybdenum and nickel ferrites showed embrittlement after short time exposures, the notch toughness improved markedly following 96 hr of aging. Furthermore, after extended holding, the initial differences in transition temperature were no longer present. Also, the rate of cooling from the subcritical temperatures had no appreciable effect on the notch toughness of these materials when heated for prolonged periods.

The embrittlement and subsequent improvement in toughness which occurred with time at the subcritical temperatures are suggestive of an aging mechanism. Figure 7 shows the effect of reheating temperature on the time necessary to produce embrittlement in specimens of normalized nickel ferrite. Molybdenum and carbon ferrite behaved similarly. The temperature-time characteristics of the embrittlement, apparent from the figure, supports a diffusion-dependent aging phenomenon.

It is also obvious from Fig. 7 that in order to develop "aging" and "overaging" within reasonable lengths of time, somewhat higher temperatures than those normally used for stress relieving were necessary.

The effect of alloying elements on the ferrites used in this investigation seemed to be twofold. In the amounts present, Ni and Mn produced a finer ferrite grain size on either air or furnace cooling from a given austenitizing temperature and, consequently, improved the notch toughness. Cr had a beneficial influence only in air cooling. Mo did not appear beneficial to grain size in any case. Both Mn and Cr increased the resistance to subcritical embrittlement while Ni and Mo had little, if any, effect.

In summary it can be said that embrittlement occurred only on furnace cooling from the austenitizing or subcritical temperatures. The subcritical embrittlement observed in these ferrites was dependent both on the time of holding at

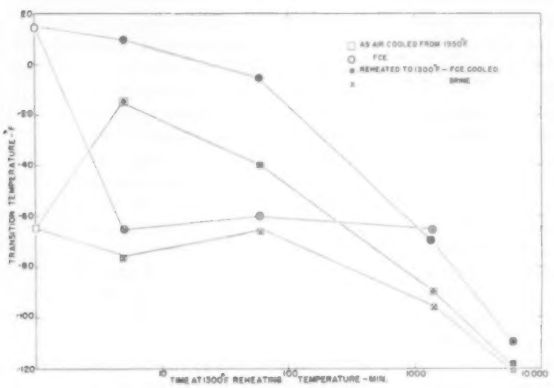

TRANSITION TEMPERATURE - °F
TIME AT 1300°F REHEATING TEMPERATURE - MIN.
AS AIR COOLED FROM 1950°F
FCE
REHEATED TO 1300°F - FCE COOLED
BRINE

Fig. 4—Molybdenum ferrite—Effect of subcritical heat treatment on the as-cooled transition temperatures. A.S.T.M. grain size No. 6.2

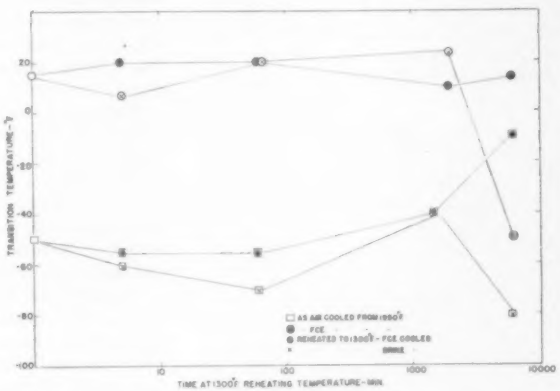

TRANSITION TEMPERATURE - °F
TIME AT 1300°F REHEATING TEMPERATURE - MIN.
AS AIR COOLED FROM 1950°F
FCE
REHEATED TO 1300°F - FCE COOLED
BRINE

Fig. 6—Chromium ferrite—Effect of subcritical heat treatment on the as-cooled transition temperatures. A.S.T.M. grain size No. 6.0

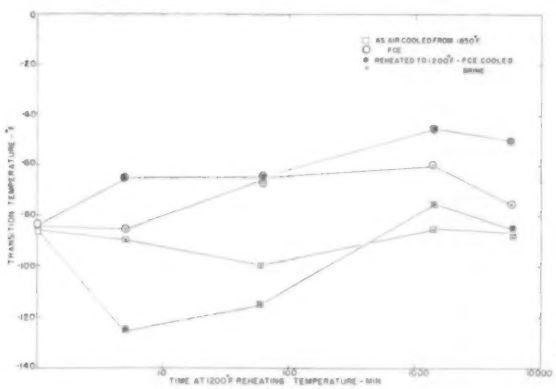

TRANSITION TEMPERATURE - °F
TIME AT 1200°F REHEATING TEMPERATURE - MIN
AS AIR COOLED FROM 1850°F
FCE
REHEATED TO 1200°F - FCE COOLED
BRINE

Fig. 5—Manganese ferrite—Effect of subcritical heat treatment on the as-cooled transition temperatures. A.S.T.M. grain size No. 6.8

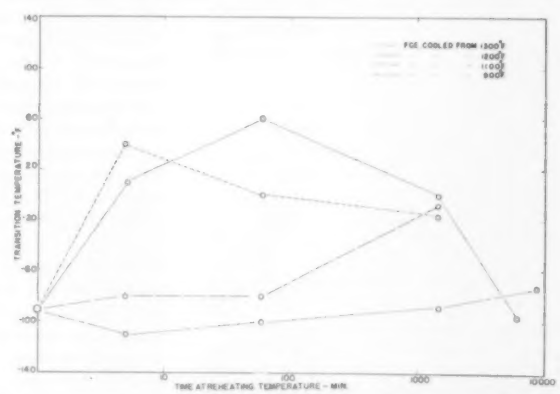
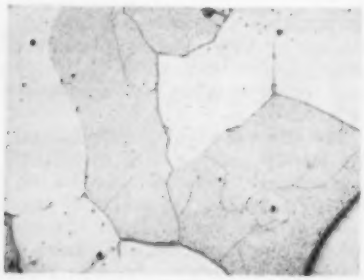
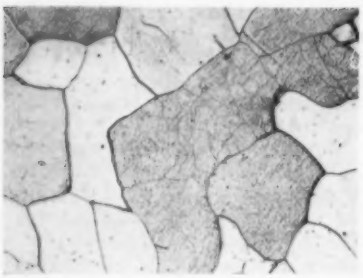


Fig. 7—Nickel ferrite—Effect of subcritical heating temperature on the holding time necessary to cause embrittlement. Specimens air cooled from austenitizing. A.S.T.M. grain size No. 6.4



Austenitized at 1750° F and furnace cooled. Ferrite-grain size 5.5



Austenitized at 2100° F and air cooled. Ferrite-grain size 5.5

Fig. 8—Substructure in plain-carbon ferrite. Etchant, 2% nital, 96% ethanol, 2% HCl and 2% $FeCl_3$. X 1000. (Reduced by $^1/_2$ upon reproduction)

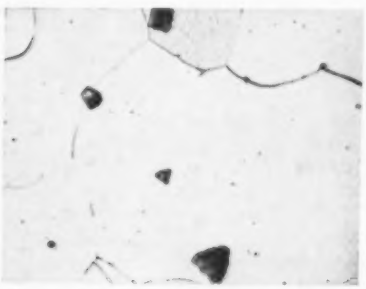


Fig. 9—Etch pit development in plain-carbon ferrite. Etchant, 2% nital, 96% ethanol, 2% HCl and 2% $FeCl_3$. X 1000. (Reduced by $^1/_2$ upon reproduction)

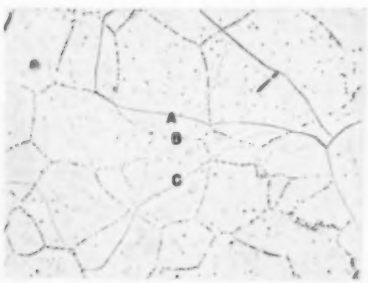


Fig. 10—Photomicrograph showing ferrite-grain boundaries, subgrain boundaries, and AlN network. Etchant, 96% ethanol, 2% HCl and 2% $FeCl_3$. Saturated picral. Plain-carbon ferrite furnace cooled from 1750° F. A, Ferrite-grain boundary; B, AlN network; C, subgrain boundary. X 1000. (Reduced by $^1/_2$ upon reproduction)

temperature and on the method of cooling therefrom. In the C, Ni and Mo ferrites, embrittlement occurred only in specimens furnace cooled from temperatures below the transformation range. Furthermore, in these ferrites, embrittlement was eliminated by 96 hr of exposure at the reheating temperature. The Cr ferrite embrittled when furnace cooled from the austenitizing temperature, but unlike C, Ni and Mo, it required extended subcritical heating times to embrittle the normalized specimens or to toughen the furnace-cooled specimens. Finally, the Mn ferrite showed no consistant response to the subcritical treatments.

Metallographic Studies

Substantial variations in the notch toughness of the ferrites were observed as a result of the heat-treating cycles employed. In an effort to relate the observed behavior to microstructural changes which may have occurred, an intensive metallographic investigation was conducted. In particular, the substructure and precipitation within the grains and at the boundaries were examined carefully.

Specimens air cooled and furnace cooled from austenitizing temperatures selected to produce the same ferrite grain size, revealed a much coarser substructure existing in the furnace-cooled specimens. An example of this is shown in Fig. 8. Samuel and Quarrell,[5] in their paper on alpha veining in Armco and other irons, indicate a similar effect of cooling rate on the substructure configuration, i.e., finer substructure with increased rates of cooling from the austenitizing temperature. It has often been noticed that substructure is not visible in every grain. This is believed to be due to orientation differences between grains. Figure 9 shows etch pits developed in grains with and without evidence of substructure. The relation of the substructure to the triangular- and square-shaped pits present in these grains supports the view that orientation accounts for the variation in sub-structure etching characteristics between the grains. Apparently those grains oriented to develop triangular (111)-type pits, are more resistant to attack by the etching reagent than the mottled grains showing (100)- or (110)-type pits. It should be pointed out that subgrains are not confined to very low-carbon irons of little structural importance. Although the literature is largely devoted to descriptions of alpha veining in ingot irons and similar materials, Northcott[8] has

Fig. 11—Extraction replica showing the network identified as AlN. Etched in picric acid, replica subsequently dry-stripped. X 5000. (Reduced by $^1/_2$ upon reproduction)

observed veining in a 0.30% carbon steel. Hence it is quite possible that substructure configuration has a practical significance in determining the notch toughness of steels used in welded structures.

Further metallographic investigation led to the discovery of the network shown in Fig. 10. This network was identified as particles of AlN by electron diffraction patterns taken on material removed during the process of replica stripping. A photograph of the AlN network made from an electron-microscope replica is included in Fig. 11. Evidently the AlN particles have precipitated at some favorable sites prior to the formation of ferrite in the γ-α transformation upon cooling. Figure 10 shows the independent existence of the AlN network and the subgrain boundaries quite clearly. Furthermore the AlN network crosses the ferrite-grain boundaries; a characteristic definitely not reported for subgrains. Microscopic observations of the ferrites in the as-rolled, as normalized and final air-cooled conditions have failed to reveal such an arrangement of AlN. Only on furnace cooling was a network made visible by careful chemical etching. A network of AlN was, however, developed in the air-cooled specimens on subcritical heating for approximately 24 hr. After 96 hr of exposure to the reheating temperatures, a coalescence of the AlN was observed. At present, the sites at which the particles of AlN are located have not been identified.

It is unlikely that the embrittlement of the C, Ni and Mo ferrites

was associated with the observed AlN network behavior since a similar network response was noted in the Cr and Mn ferrites with no accompanying embrittlement.

Metallographic studies of the as-cooled, embrittled and "overaged" specimens did not reveal any significant differences in the microstructure of these specimens. No change in substructure configuration could be noted as a result of aging; an observation which agrees with the work of Samuel and Quarrell[5] who have reported extreme stability in substructure with extended subcritical heating. Grain-boundary and subgrain-boundary studies with the electron microscope have failed to reveal any phase precipitation in these regions. The inability to detect a grain-boundary phase should not, however, be construed to mean that a phase was not precipitated. It is quite possible that the etchant removed any phase which may have been present, thereby making it impossible to observe. Hopkins and Tipler[6] reported severe embrittlement in iron due to the preferential segregation of phosphorus in the grain boundaries. Although phosphorus segregation was detected by radioactive tracer and counting techniques, the authors were unable to observe any phase precipitation with the electron microscope. The embrittlement encountered in the present work may be due to grain-boundary segregation of phosphorus or other tramp elements such as C, N or O which are known to have a deleterious effect on notch toughness.

Fracture studies on all of the ferrites indicate that brittle cleavage failure is usually initiated at the grain boundaries. The majority of specimens tested below their transition temperatures absorbed only small amounts of energy with little accompanying plastic deformation. In those specimens which did absorb sufficient energy to deform plastically, mechanical twins have been observed. If it is assumed that microcracks originate at the wide end of the crack, Fig. 12 (a) indicates cracking has initiated at the mechanical twin marked *C*. A second crack, marked *A*, preceded by a twin, marked *B*, can also be seen in the photomicrograph. It should be emphasized, however, that observations of cracks associated with twins were extremely rare. The photomicrograph is presented only to point out the possibility that cracking may, in some instances, be initiated by mechanical twins. Another interesting observation concerning the relationship between microcracks and twins can be seen in Fig. 12 (b). In this case the microcrack which has originated at the ferrite-grain boundary is deflected by the twin at point *B* and apparently cleaves along the twin for some distance until finally assuming the original cleavage direction.

Figure 13 shows a mechanical twin which has been halted at the junction of some AlN stringers. Should mechanical twins be able to initiate brittle cleavage fracture then one might conjecture that obstacles which are capable of arresting twin progress might conceivably act as a stress concentration and thus promote fracture. However, no cracks of this type were observed in any of the specimens studied.

As mentioned previously, in the majority of specimens fracture was transcrystalline in nature. In the embrittled specimens, however, some intergranular cracking was apparent. Hence it is quite possible that grain-boundary segregation is responsible for the observed embrittlement either by providing an easier path for fracture or, possibly, by acting as a barrier to dislocation movement which, according to Zener,[7] could lead to the initiation of a transcrystalline crack.

Summary

The results of this investigation can be summarized as follows:

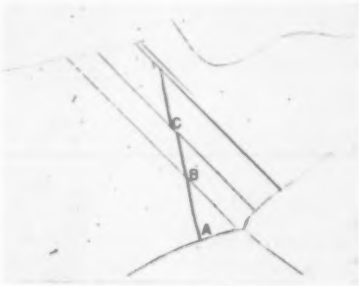
1. The notch toughness of ferrite, which is the predominant phase in structural steels, was controlled primarily by its grain size. However, grain size was not the only important microstructural variable.

2. In the absence of alloys, ferrite was embrittled by furnace cooling through the temperature range below transformation. This was true whether cooling followed austenitizing or a reheating treatment below transformation. Holding the ferrite at 1300° F for 96 hr eliminated this embrittlement regardless of subsequent cooling.

3. Mn and Ni increased the toughness of ferrite largely by refining the ferrite-grain size. The effect of Cr was generally weaker in this respect while Mo was ineffective.

4. Ni and Mo had no effect on the subcritical embrittlement observed in the alloy-free ferrite. Mn appeared to suppress this embrittlement. Cr retarded the changes in toughness resulting from subcritical treatments but did not effect the embrittlement produced by furnace cooling from the austenitizing temperature.

(a) Microcrack apparently initiated at the mechanical twin marked C. A second microcrack (A) following or preceded by a mechanical twin (B) is also visible.



(b) Microcrack initiated at ferrite-grain boundary (A), deflected by twin at points (B) and (C).

Fig. 12—Plain-carbon ferrite specimens prepared from fractured Charpy bars. Etchant, 2% nital. X 1000. (Reduced by $^1/_2$ upon reproduction)

Fig. 13—Plain-carbon ferrite specimen prepared from fractured Charpy bar. Mechanical twin progress halted by AlN network junction at point A. Etchant, 2% nital saturated picral. X 1000. (Reduced by $^1/_2$ upon reproduction)

5. Careful examination of the microstructural details using the optical and electron microscopes did not reveal changes in the microstructure which could be associated with the subcritical embrittlement. The presence of substructure and precipitates was given special consideration.

6. Observation of microcrack initiation supported the results reported previously for ferrite-pearlite aggregates, i.e., cleavage cracks originated at ferrite-grain boundaries and possibly at mechanical twins. While cracking was normally trans-

crystalline, those specimens which were subcritically embrittled exhibited some intergranular cracking.

Acknowledgment

The authors are grateful to the International Nickel Co. which provided the funds to make this investigation possible. They also wish to acknowledge the cooperation of the Bayonne Laboratory of the International Nickel Co. for their assistance in the electron-microscope studies.

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Cost of Cooperative Research

BY W. SPRARAGEN

The budget of the Welding Research Council has grown steadily since it was first launched in 1935 by a grant of $5000 from the Engineering Foundation. Its budget for the current fiscal year is now over $680,000.

The surprising thing, however, is that it is not two or three times this amount. Certainly there are many problems that need solution. The solution of these problems would in the long run save industry 100 times their original cost in one way or another. Then, why is the growth of the Council not more rapid? Is it lack of adequate salesmanship? Perhaps! However, it is the opinion of the author that the answer is more complex.

First of all, what are the advantages and drawbacks of cooperative research? On the side of advantages may be cited:

1. The cost for a specific research is spread over many companies and industries.
2. The chances of solutions are much greater because a diversified talent of scientists and engineers of many universities, companies and government agencies are brought to bear on the problem.
3. The results are more readily and widely accepted.
4. There is an indirect benefit to industry in the training in the universities of young men who after graduation become available to Industry.

The disadvantages of cooperative research are equally apparent.

1. No single company can utilize the results solely for its own benefit.
2. The results of a broad program of research must very often be translated to apply to the product and methods of a specific company.

Those that are closely affiliated with cooperative research would quickly point out that the Council, for example, does not undertake research that leads to patents. Moreover, it is often just as difficult and time consuming to utilize the results of research coming from the laboratories of their own companies.

Therefore the answer for the slowness of growth of cooperative research must lie somewhere else.

In his forty years of experience in financing cooperative research in several branches of Engineering, the author believes the following reasons are more pertinent.

1. Requests for funds for cooperative research generally lodge in the hands of a "Contributions Committee" that looks up such requests as "worthy causes" which must compete with demands for contributions from "Red Cross," "Cancer," "Boy Scouts," etc. Obviously, it is going to be difficult to attach such expense to the "research" or "manufacturing" budgets of a specific company. Yet, undoubtedly, the results of such cooperative research would cut the cost of private research or manufacturing programs.

2. The second real reason lies in "human nature." One does not like to go to a superior officer and admit the lack of knowledge in a specific field or to spend the time and effort to thoroughly understand the significance of a piece of research (regardless of where conducted) and changeover methods now in use, which, while not the best, do work.

W. SPRARAGEN is Director, Welding Research Council.

Evaluation of Weld-Joint Flaws as Initiating Points of Brittle Fracture Part II

Objective of investigation is to determine the conditions required to initiate brittle fractures from flaws 4 in. or less in length

BY R. P. SOPHER, A. L. LOWE, JR., D. C. MARTIN AND P. J. RIEPPEL

Introduction

Numerous investigations of the causes of brittle fracture in ships have been undertaken in the past ten years. Attention has recently been given to the part that weld flaws have played in the initiation of brittle fractures in welded structures. The lack of knowledge concerning the types and sizes of flaws that may be dangerous in a ship structure prompted this investigation, which has been advised by the Ship Structure Subcommittee and sponsored by the Ship Structure Committee.

The principal objective was to investigate the conditions required to initiate brittle fractures from flaws 4 in. or less in length. The information obtained from flaws greater than 4 in. in length has been reported and published.[1] It was believed that the information gained would aid in establishing production, inspection and repair procedures for use in ship construction. The work described in this paper is the concluding phase of this investigation.

Review of Previous Work on Flaw Evaluation

The literature covering the broad subject of brittle fracture was carefully surveyed. This survey was necessary to determine (1) what was required of a laboratory test specimen, and (2) what the design of specimen should be if service conditions were to be simulated. After an extensive study of the subject of brittle fracture, it was decided to use a sphere approximately 9 ft in diameter as the testing apparatus. The test specimen that contained the weld flaw was welded in place as as integral part of the sphere wall. The stress condition in the sphere wall at some remote distance from the flaw front was essentially biaxial. It was intended that the stress field in the sphere wall would simulate stress conditions in the deck or hull of a ship where a biaxial stress field is known to exist.

The most serious types of defects in welds are believed to be cracks and lack of fusion and, of these, weld cracks seem to be most dangerous on the basis of past experience. Perhaps the reason for this is the very sharp radius at the flaw or crack front, which produces high stress concentration. In view of this, the first studies were confined to weld cracks and lack-of-fusion-type flaws and, more specifically, to the effect of size of flaw on the applied stress required to initiate a brittle fracture under static loading. From the studies, the following conclusions were drawn:

1. Brittle fractures were initiated at applied stresses well below the yield strength of the test plate provided the crack was 4 in. long or longer.

2. As the length of the crack increased, the applied fracture stress decreased. An increase in crack depth decreased the applied fracture stress only slightly. These data are shown in Fig. 1.

3. When weld cracks ended in sound E6010 weld metals, brittle fractures did not initiate. In some tests, ductile fractures occurred even though the Charpy V-notch 15 ft-lb transition temperature of the base plate was above the test temperature.

4. In general, the applied fracture stresses were lowered by the addition of residual or reaction stresses to the stress system. However, the magnitudes of residual or reaction stresses were not known in these tests.

5. Brittle fractures were initiated from lack-of-fusion flaws in welds. The applied fracture stress decreased somewhat with increase of depth of flaw.

The important finding that the flaw had to be 4 in. long or longer in order to give a failure at applied stresses lower than the yield strength of the ABS-B steel base material does not agree with the reports from service failures. Apparently the state of stress in the area of the flaw front was not the same for the laboratory tests and the service failures. It appeared that stresses, other than those calculated to be present in a ship deck, might be playing a part in initiating brittle fracture. The phase of the investigation reported here was thus directed toward a study of the effect of residual and reaction stresses on the magnitude of applied stress required for the initiation of a brittle fracture; it is hoped that a knowledge of the effects of residual stress may help to explain the discrepancies between service failures and laboratory studies.

Test Procedure

The sphere that was designed and built during the initial study of weld flaws was used in the final

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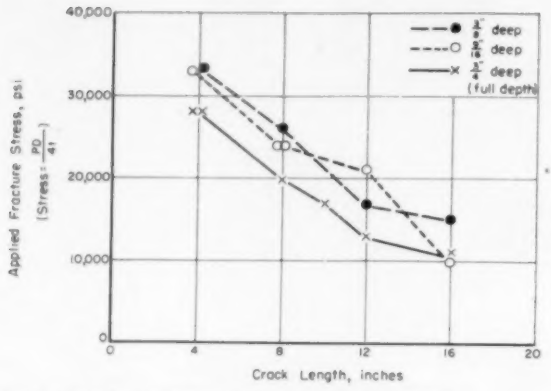


Fig. 1—Relation between crack length, crack depth and applied stress required to initiate brittle fracture

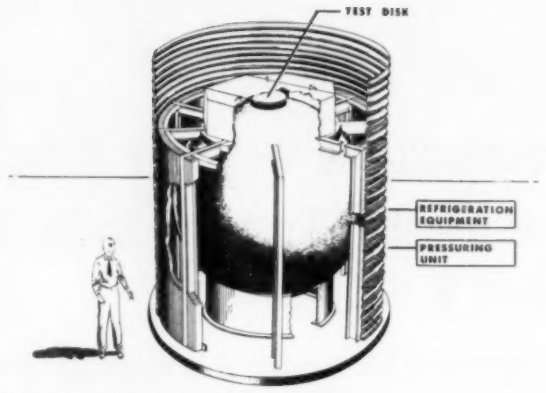


Fig. 2—Cutaway drawing showing testing apparatus and supplementary equipment

phase of the investigation. Briefly, the test apparatus was a 9-ft-diam sphere made of 3/4-in. high-yield-strength low-alloy steel with good notch toughness. The test plate was a 3/4-in.-thick by 23-in.-diam circular curved disk, which was welded into the wall of the sphere. The flaw to be evaluated was fabricated into the central area of the 23-in.-diam test specimen before the specimen was welded into the sphere. In effect, this made the entire sphere the test specimen. The test disk was fabricated from the base material being studied. The chemical composition and mechanical properties of the ABS-B steel used in this phase of the program are given in Table 1. A sketch of the testing apparatus is shown in Fig. 2.

Since it was desirable to study the effect of residual and reaction stress on the applied fracture stress, it was necessary to apply a load of some type across the flaw front to simulate the residual stresses found in service. The load was applied so that the maximum stress was normal to the flaw. The residual and reaction stresses were applied by either a hydraulic ram, circular-patch-type specimen, or weld deposits made on each side of and parallel to the test flaw. The individual methods used for applying the residual and reaction stresses are discussed later. After the application of the residual stress, the strain measurements were recorded and the sphere prepared for testing. The objective was to apply a known amount of residual stress that was below the fracture stress, then load the sphere by hydrostatic pressure until the crack initiated and propagated in a brittle manner.

The temperature of the entire sphere was lowered below the Charpy V-notch 15 ft-lb transition temperature of the ABS-B steel. The temperatures were obtained by circulating a brine solution through the sphere. After the desired test temperature was reached, the sphere was loaded hydrostatically. During the loading cycle, the pressure was held constant at each 100-psi increment for approximately 30 sec to record strain-gage readings. This procedure was repeated until a brittle fracture was initiated. None of the fractures initiated during the 30-sec interval. If the fracture did not initiate before the applied stress reached 33,000 psi, the test was discontinued. After failure, the test specimen was removed from the sphere for examination of the fracture face.

Various types of flaws were used to determine the effects of residual reaction stresses on the applied stress required to initiate brittle fractures. To reduce the variables that might exist in the nonuniformity of a weld-metal crack, a simulated weld flaw prepared with a band saw was employed. The flaw front was then extended an additional 1/8 in. at each end with a 0.007-in.-thick jeweler's blade, as shown in Specimen A, Fig 3. This type of flaw was used in the first test of each flaw length studied. Specimen B in Fig. 3 is an illustration of a typical buried flaw. The flaw was created from a full-depth sawcut flaw (illustrated in Specimen A) by depositing an E6010 weld metal over the saw cut. The depth of the flaw was controlled by varying the depth of penetration during welding.

Specimen C of Fig. 3 is a full-depth weld-metal flaw. The flaw was made by placing cast iron chips in the weld groove and welding over them with an E6010 electrode. Upon completion, the weld deposit was radiographed to determine the exact length and configuration of the flaw. A metallurgical bond existed between the weld metal and base metal; consequently, the crack front was in the heat-affected base metal.

In several tests, the fractures propagated outside the 23-in.-diam ABS-B steel test specimen and into the notch-tough steel sphere. These tears were repaired with low-hydrogen E10016-type elec-

Table 1—Chemical Composition and Mechanical Properties of ABS-B Steel[a]

Chemical composition	%	Mechanical properties	
Carbon	0.21	Yield strength, psi	30,700
Manganese	0.80	Ultimate strength, psi	59,400
Phosphorus	0.019	Thickness, in.	3/4
Sulfur	0.034	Elongation in 2 in., %	55.3
Silicon	0.04	Elongation in 8 in., %	31.7
Aluminum	0.003	15 ft-lb Charpy V-notch transition temperature, °F	40[a]
Nickel	0.10	Tear-test transition temperature, °F	100
Copper	0.05		
Chromium	0.04		
Molybdenum	0.01		
Nitrogen	0.005		
Vanadium	0.01		
Titanium	0.004		

[a] Transition temperature of cold-formed disks, tests performed at Battelle.

trodes. To reduce the number of repairs, a method was devised to deflect the propagating crack into the weld joint between the test specimen and the notch-tough steel sphere. The deflection of the crack was accomplished by welding notch-tough steel wedges near the weld joining the test specimen and the sphere, and opposite the flaw fronts, but a sufficient distance from the flaw front so that the state of stress at the flaw front was not effected by their presence. A specimen in which the notch-tough wedges deflected the propagating crack is shown in Fig. 4. After the idea was conceived, these wedges were used in all tests and were successful in preventing damage to the sphere.

Strain gages and an optical comparator were used to measure the strain during testing. Standard SR-4 type strain gages were used to measure the strain resulting from the hydrostatic loading of the sphere. These gages were used at or below room temperature and were satisfactory as long as they were properly waterproofed. However, they were not satisfactory in areas where a weld had to be made. The high temperatures encountered during welding ruined those gages in the vicinity of the welds. High-temperature strain gages were used and found satisfactory provided the gage was properly bonded to the base material. However, the proper application of the gages consumed a lot of time.

To reduce the amount of time required for each test, an optical comparator was used instead of the high-temperature gages. The distance between scribe marks was measured with the optical comparator before and after welding to determine the residual strains produced by welding. Although the use of the optical comparator did not permit a continuous check of the strains, it did give very good results as to the strain produced by welding in the area of the flaw front at the surface of the plate.

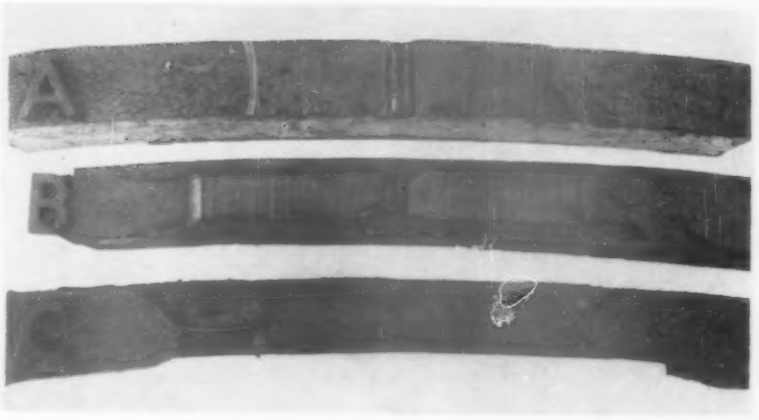


Fig. 3—Three types of flaws studied. A, full-depth jeweler's saw cut. B, Buried flaw. C, Full-depth weld-metal crack

Fig. 4—Test specimen in which notch-tough steel wedges welded into the specimen prevented the brittle fracture from propagating into the sphere

Methods Used to Produce Residual and Reaction Stresses in Test Specimens

At the beginning of the study, it was realized that the introduction of a known amount of residual or reaction stress in the area of the flaw front was very important. Consequently, considerable effort was expended to find a suitable method of producing these stresses. There appeared to be two methods that could be adapted to this particular test specimen: (1) the use of weld deposits, and (2) the use of a mechanical loading system to induce stresses in the material adjacent to the prepared crack front. The methods are described hereafter in detail.

Producing Residual and Reaction Stresses by Welding

The circular-patch specimen was the first configuration used to produce a residual and reaction stress across the flaw front. These tests, however, were not very successful and were discontinued because it was difficult to control the amount of induced stresses.

Weld deposits parallel to and on each side of the flaw were also employed as a method of producing residual and reaction stresses at the flaw front. A sketch of this type of specimen is shown in Fig. 5. This procedure would simulate service conditions where welding might produce or influence the reaction stresses in a welded structure.

A preliminary study was made to determine the welding procedures necessary to produce high residual or reaction stresses at the flaw front. These studies showed that yield-point stresses could be produced in the base plate between two parallel welds provided high-yield-strength weld metals were deposited.

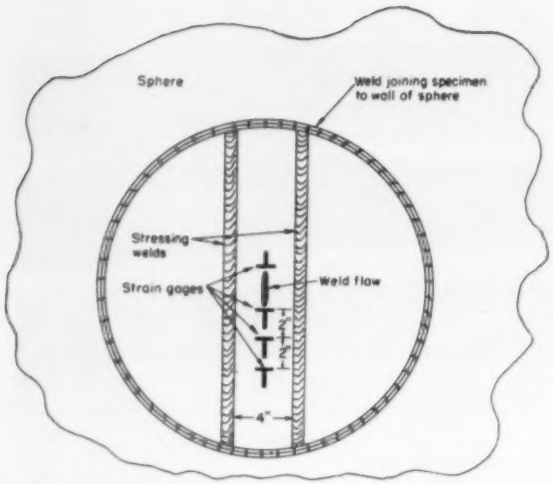
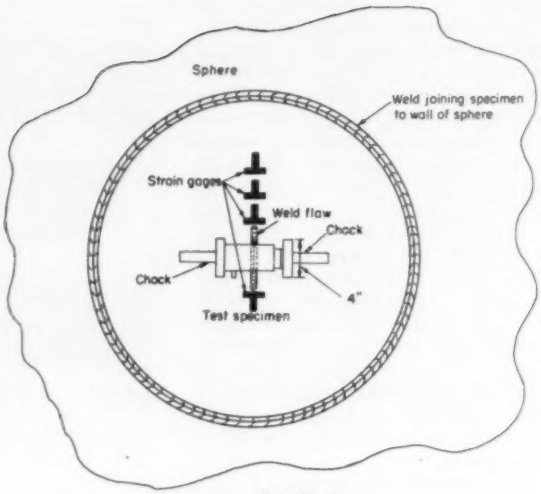


Fig. 5—Sketch showing use of welding to produce residual and reaction stresses in area of flaw



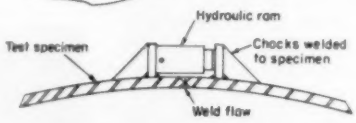


Fig. 6—Sketch showing the use of a hydraulic ram to produce reaction stresses at the flaw fronts

The parallel weld technique was used by preparing a groove on each side of the flaw before welding the circular-test disk into the sphere. The weld containing the flaw was then deposited in the center of the test specimen, and the test specimen was welded into the sphere. Gage marks were made on the site of the SR-4 strain-gage locations (shown in Fig. 5), and measurements were recorded. Weld metal was then deposited in the parallel grooves. After the specimen was cooled to room temperature, the strain between the gage marks was measured.

The residual stress was obtained from the difference between the strain measurements made before and after the parallel welds were completed. The residual stresses in the area of the flaw varied from the yield point of the base steel to a low value of 2000 psi.

Producing Reaction Stresses by Mechanical Means

Quite often during the construction of ships, the plates to be joined by welding are jacked into position to give proper fit. In these instances, various degrees of reaction stresses remain in the structure after welding. Butt welds that contain flaws may possibly be stressed in this manner. Therefore, in an attempt to simulate this condition on a laboratory scale, a mechanical device was used to introduce these stresses in the area of the flaw front of the test specimen. This condition was accomplished by welding two chocks on opposite sides of the flaw, as shown in Fig. 6. These chocks were welded to the test disk before the

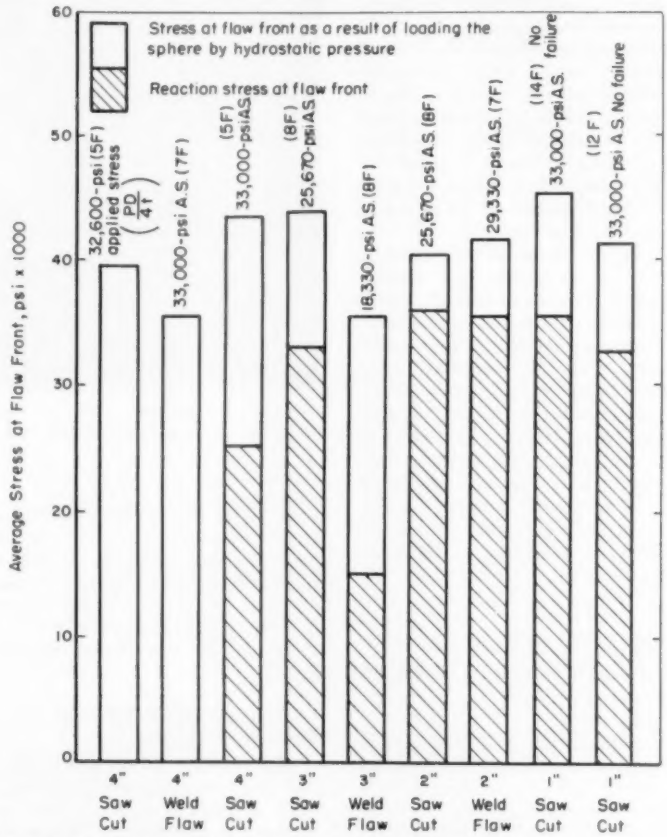


Fig. 7—Effect of reaction stress on the initiation of brittle fractures from simulated weld flaws

Reaction stresses introduced by hydraulic ram. All plotted stresses were calculated from strain measurements at the flaw front and the uniaxial stress-strain curve.

flaw was prepared. This procedure eliminated any stresses in the area of the flaw front resulting from welding the chocks to the disk. The load across the flaw front was supplied by a hydraulic ram placed between the chocks. The strain introduced from the load of the ram was measured by SR-4 strain gages placed at selected locations in the area of the flaw front. A constant pressure was maintained on the hydraulic ram during the loading of the sphere.

Study of Influence of Length and Depth of Flaw and Triaxiality on the Applied Stress Required to Initiate Brittle Fracture

Effect of Flaw Length on Fracture Initiation

The jeweler's saw-cut notch and weld-metal flaw was employed in these tests to study the effect of flaw length on the stress required to initiate brittle fractures. These flaws ranged in length from 4 to 1 in. The reaction stress was applied across the fronts of the flaws by means of the hydraulic ram. The test results indicated that: (1) the length or the type of flaw had little influence on the average fracture stress required to initiate failure, as shown in Fig. 7; (2) reaction stresses reduced the applied stress required for fracture; (3) it made little, if any difference how the stress was applied, whether by loading the sphere by hydrostatic pressure or by applying reaction stresses by various means and then loading the sphere until fracture occurred.

The strain measurements from which the stress was computed were taken on the surface of the plate at the flaw front. The average fracture stress was obtained from the true stress-strain curve of the base material, as shown in Fig. 8. Although this curve was obtained from a specimen tested in uniaxial tension and the specimen in the sphere was stressed biaxially, the stress-strain curve was believed to be useful in obtaining an estimate of the stress that existed in the area of the flaw front. Furthermore, the amount of strain that occurred normal to the flaw front was much greater than the strain parallel to the flaw front. The average fracture stress, computed from strain measured on the plate's surface at the flaw front, was approximately the same for all the specimens. Any differences that existed in these stress values might be the result of nonuniform placement of the strain gages with respect to the crack front.

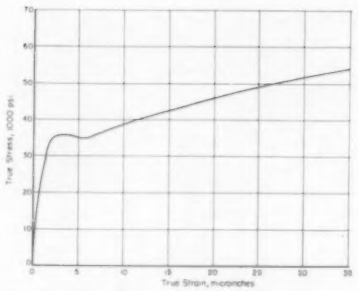


Fig. 8—True stress-strain curve for ABS-grade B ship steel

Since there was considerable plastic deformation at the flaw front prior to fracture, any differences in performance between the specimens are illustrated by variations in strain more clearly than by variations in stress. The strain plot is shown in Fig. 9. The total strain of the specimens containing the 4- and 3-in. weld flaws was considerably lower than the strain recorded for the other specimens. The specimen containing the 4-in. flaw may not be too representative because the test was originally planned to study a buried flaw. A fracture could not be initiated from the buried flaw; therefore the specimen was modified to give a full-depth flaw. Because of this modification, it is possible that some residual stresses that were not recorded remained at the flaw front from the original loading of the full-depth flaw. There is no apparent reason why less strain was required to initiate fracture from the 3-in. weld flaw than from the other flaws. There was considerable difference in the amount of strain recorded from the two specimens containing the 4-in. saw-cut flaws. In these two specimens, the strain gages were accurately oriented in the same geometric arrangement with respect to the saw-cut front. With this accuracy, there was a difference of 5000 microinches of strain between the specimens prior to fracture. Since this amount of scatter existed between these two tests, the differences in strain for the other specimens might be considered as normal scatter, except for the 3-in. weld-flaw specimen.

No fractures were initiated from either the 1-in. saw cuts or the 1-in. weld flaws. In the one specimen containing a 1-in. saw-cut flaw, more strain occurred than for any other length of flaw. A fracture would be expected to initiate from the 1-in. flaw if the amount of plastic deformation (strain) at fracture is relatively constant regardless of flaw length. The strain recorded from the specimen containing the other 1-in. saw-cut flaw and two 1-in. weld flaws was in the order of 10,000 to 15,000 microinches, which is approximately the amount recorded from the longer flaws. The testing conditions and apparatus did not permit loading the 1-in. flaws to failure.

A series of tests was made in which the weld flaws were stressed by depositing welds on each side of and parallel to the flaw. As mentioned previously, yield-point stresses were recorded in the base material when reaction stresses were

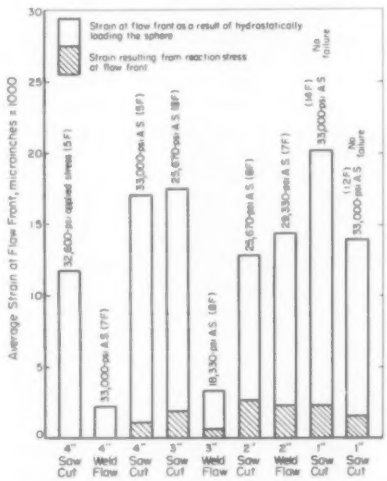

Strain at flaw front as a result of hydrostatically loading the sphere
Strain resulting from reaction stress at flaw front
Average Strain at Flaw Front, microinches x 1000
4" Saw Cut
4" Weld Flaw
4" Saw Cut
3" Saw Cut
3" Weld Flaw
2" Saw Cut
2" Weld Flaw
1" Saw Cut
1" Saw Cut

Fig. 9—Effect of reaction strain on the total strain required to initiate brittle fractures from simulated weld flaws (jeweler's saw cut). Reaction strain introduced by hydraulic ram

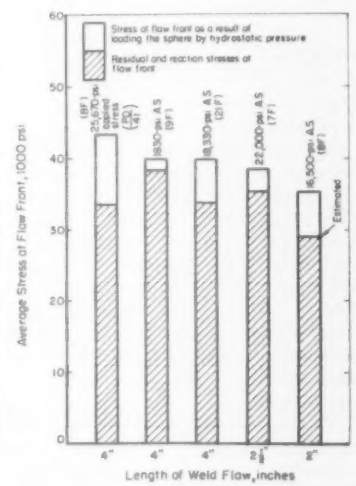

Stress at flaw front as a result of loading the sphere by hydrostatic pressure
Residual and reaction stresses at flaw front
Average Stress at Flaw Front, 1000 psi
Length of Weld Flaw, inches

Fig. 10—Effect of residual and reaction stresses introduced by welding on the initiation of brittle fractures from weld flaws

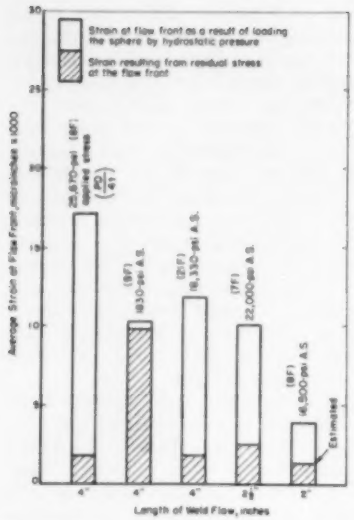

Strain at flaw front as a result of loading the sphere by hydrostatic pressure
Strain resulting from residual stress at the flaw front
Average Strain at Flaw Front, microinches x 1000
Length of Weld Flaw, inches
Estimated

Fig. 11—Effect of residual and reaction strain from welding on the average strain required to initiate brittle fractures from weld flaws

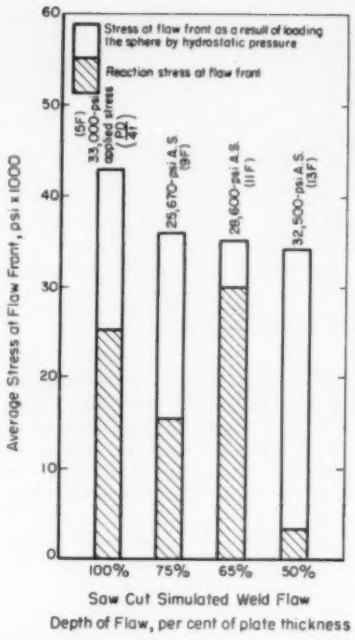

Stress at flaw front as a result of loading the sphere by hydrostatic pressure
Reaction stress at flaw front
Average Stress at Flaw Front, psi x 1000
100%
75%
65%
50%
Saw Cut Simulated Weld Flaw
Depth of Flaw, per cent of plate thickness

Fig. 12—Effect of reaction stress on the initiation of brittle fracture from 4-in. flaws of various depths

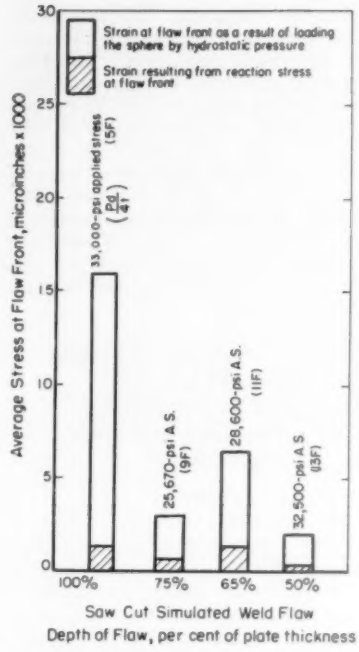

Strain at flaw front as a result of loading the sphere by hydrostatic pressure
Strain resulting from reaction stress at flaw front
Average Stress at Flaw Front, microinches x 1000
100%
75%
65%
50%
Saw Cut Simulated Weld Flaw
Depth of Flaw, per cent of plate thickness

Fig. 13—Effect of reaction strain on the initiation of brittle fracture from 4-in. flaws of various depths

produced in this manner. The test results are shown in Fig. 10. In all of the test specimens, a high residual stress across the flaw front resulted in brittle fracture initiating at rather low applied stresses. The second 4-in.-long weld flaw tested is of particular interest in this series of tests. The residual stress at the flaw front at the start of the test was 38,200 psi (considerable deformation had occurred) and after applying an additional stress of approximately 1800 psi, a brittle fracture initiated from the weld flaw. These test results illustrate the magnitude to which residual and reaction stresses can be built up within a structure. With such high residual stresses present, little additional stress is required to initiate fracture if the temperature is low enough.

The average strain at the flaw front of each specimen containing only a weld flaw is plotted in Fig, 11. These measurements were used to determine the stress shown in Fig. 10. A plot of the strain illustrates differences in the amount of plastic flow in the area of flaw front more clearly than a plot of the stress, because considerable plastic strain occurs without any appreciable increase in stress.

Most of the deformation occurred in the prestressing (residual) stage of the loading cycle for the one 4-in. flaw. In another flaw of equal length, most of the strain occurred from loading the sphere by hydrostatic pressure. The total strains were approximately the same. Consequently, it appears that the majority of the strain can be produced at any stage of stressing without influencing the total strain at fracture. The total strain recorded for the $2^1/_2$-in. flaw is also of the same magnitude as for the 4-in. flaws. The amount of strain recorded for the specimen containing the 2-in. flaw may not be very accurate, because the specimen was originally stressed as a buried flaw. Because a fracture did not initiate from the buried flaw, the flaw was modified to give a full-depth flaw. In the course of this modification, it is believed that residual stresses were introduced and were not recorded. This chain of events may be the reason for the low strain measurements prior to fracture. However, these strain recordings are approximately the same as those shown in Fig. 9 for the 3- and 4-in. weld flaws. The wide range of strain recorded prior to the initiation of the weld flaws may be the result of variations in the location of the crack front. Although great care was exercised in preparing the weld flaw, there was always the possibility of lack of fusion near the crack front. In some of the specimens, the crack front may have been in the high-carbon weld metal, while in others it may have been in the heat-affected zone of the base plate. The scatter in strain measurements also may be attributed to the inability to locate the strain gages at the same location on each specimen with respect to the flaw front.

Effect of Flaw Depth on Fracture Initiation

In the previous work on the project, it was found that flaw depth had little effect on the applied fracture stress. These data are shown in Fig. 1 for flaws 4 in. or greater in length. In order to initiate brittle fracture from the 4-in. flaws, the crack had first to open to at least one surface of the plate. During this past year, a series of tests was made with 4-in. flaws of various depths that were completely buried; that is, sound weld metal was deposited over the flaw on each surface. Specimen B shown in Fig. 3 is a typical flaw of this type.

A plot of the average fracture stress measured in the vicinity of the flaw front is shown in Fig. 12. A full-depth flaw was included in this series of tests for comparison purposes. All of the flaw fronts were prepared with a jeweler's saw blade and the reaction stress was applied with the hydraulic ram.

The average fracture stress was somewhat higher for the full-depth flaw than for the buried flaws. There was little difference in the average fracture stress of the specimens containing the buried flaws. Less strain was required to initiate a fracture from buried flaws than

from a full-depth flaw, as shown in Fig. 13. As mentioned previously, an E6010 weld metal was deposited on the outer surfaces of the buried flaws. Strain gages were placed at the center and at the ends of the flaws. Because of the geometry of the joint, the maximum strain occurred over the center of the flaw. The limits of the strain gages in the center of the flaw were exceeded first. Since these gages were attached to the ductile E6010 weld metal, considerable strain was recorded before failure. In no case were the failures in the weld metal brittle. Although the strain gages in the center of the flaw failed first, this occurrence does not necessarily mean that the flaw opened to the surface prior to extending lengthwise. Less strain could occur at the flaw front than over the center of the flaw and still have fracture initiate at the flaw front. However, it is of interest that the amount of strain on the plate surface prior to fracture was lower for the buried flaws than for any of the full-depth flaws prepared with the jeweler's saw blade. Although the data are quite limited, they are of some significance. It would be interesting to know if the fracture of the buried flaw opens to the surface first or if it extends lengthwise.

Effect of Triaxiality on Fracture Initiation

As the state of initial stress approaches triaxiality, plastic deformation prior to fracture is decreased. In the tests described in the previous sections, the state of stress at a remote distance from the crack front was biaxial. Some degree of triaxiality exists at the crack front as a result of constraining the plastically deformed metal from further deformation; even under these conditions, considerable plastic deformation occurred on the surface of the plate at the crack front. If this material was further constrained, the degree of triaxiality would be increased, and failure would be expected to occur at a lower average applied stress as calculated from the elastic strain measured on the wall of the sphere.

Service failures have been reported that have initiated from small flaws at low applied stresses. In an attempt to reproduce this type of service condition in a laboratory test, an 8-in. square structure was fabricated from $^3/_4$-in.-thick plate and welded into the test specimen, as shown in Fig. 14. Two 4-in.-long full-depth weld flaws were made in the test specimen and located at diagonally opposite corners of the box, in such a manner that one flaw lay in the direction of rolling and the other perpendicular to the direction of rolling of the test-specimen plate.

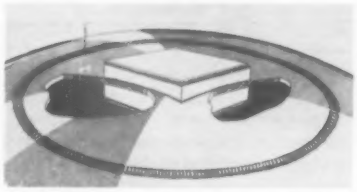


Fig. 14—Sketch of specimen with structure used to increase the degree of triaxiality near the flaw

An applied stress of approximately 6600 psi, caused by loading the sphere by hydrostatic pressure, propagated the flaw that was parallel to the direction of rolling for a distance of approximately $1^1/_2$ in. The test was continued and the flaw perpendicular to the direction of rolling propagated approximately 3 in. at an applied stress of 7400 psi. The sphere wall was further stressed to 33,000 psi without any further increase in the length of the cracks.

In previous work, at least a 30,000-psi applied stress was required to initiate fracture from a 4-in. flaw in a specimen highly stressed in only two dimensions. A point of interest to be noted is that the flaw stopped after it propagated for a distance. One explanation for the termination of the fracture was that the flaw entered an area of compression stresses that probably existed from the weld joint between the test disk and sphere wall. The applied tensile stress may not have been high enough to overcome these compressive stresses and propagate fracture in this area.

Discussion

One of the requirements for propagation of a brittle fracture in steel is to have sufficient elastic-strain energy in the system to cause continuing separation once the crack is initiated. Another requirement is to ensure that some plastic deformation occurs at the crack front prior to the initiation of the fracture. These required conditions were produced with the laboratory testing apparatus used in this study. Although the primary objective was to study crack initiation, it was necessary to produce brittle fracture to simulate reported service failures. Once the brittle fracture was initiated and propagated in the ABS-B steel, fracture was terminated in a notch-tough steel without serious damage to the test vessel. Brittle fractures were initiated from 2-in. flaws at applied stresses of one-third the yield strength, in addition to the residual and reaction stresses. These data then compare favorably with the reports of service failures that occurred at 15,000 psi applied stress or lower.

Residual and reaction stresses have a very important influence on the stress required to initiate a brittle fracture from actual weld flaws and simulated weld flaws (jeweler's saw cuts). In fact, in one test a brittle fracture was initiated at an applied stress of only 2000 psi after residual and reaction stresses were introduced in the area of the flaw front. However, the total average fracture stress at the flaw front (as measured on the surface of the plate) was about 40,000 psi. This suggests that most fractures initiating from small flaws in the deck of ships, which may be considered as a field of biaxial tension stresses, did not fail from the low applied stresses only. An auxiliary stress must have been present.

All of the laboratory tests in which brittle fracture occurred were conducted below the 15 ft-lb transition temperature of the base steel. The test temperatures also were below those encountered during service failures. Since there was considerable plastic deformation at the flaw front of the laboratory specimens, there must have been considerable plastic deformation at the flaw front of the service failures. This assumption can be made only if the states of stress at the flaw fronts were the same. It would have been desirable to have initiated brittle fractures from flaws 1 in. or less in length in order to simulate some of the service failures. It has been reported by Williams, *et al.*, that most of the fractures that initiated from small flaws (1 in. or less in length) were not in a stress field of biaxial tension (excluding the triaxiality at the crack front).[3] In most cases, a third structural member was involved. This apparently produced a more complex stress system when residual and reaction stresses were present by providing more constraint. An attempt was made to simulate this condition through use of the test specimen in which a structure was built into the circular disk. A brittle fracture was initiated from a 4-in. flaw at an applied stress of 6600 psi. With sufficient experimentation, it appears possible that brittle fractures could be initiated from small flaws (1 in. or less) at low applied stress

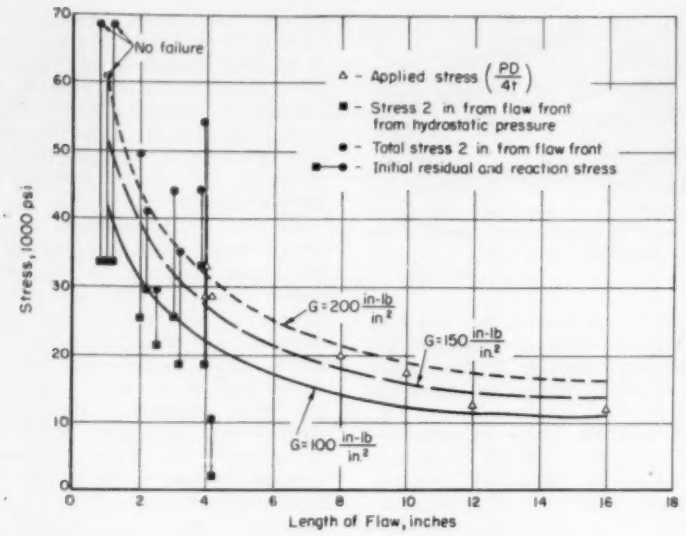


Fig. 15—Relationship of average stress for initiation of brittle fracture with length of initial flaw

levels if sufficient constraint is provided at the flaw front.

The data illustrate that, as the flaw or crack length is increased, the applied fracture stress decreases. This condition is predictable from the familiar Griffith equation as modified by Irwin and Kies for application to brittle fracture in metals.[4] This study provided considerable data that were evaluated, using the modified equation, to ascertain whether any correlation existed between the experimental results and the theoretical values that could be obtained.

As a first approximation, the equation, $G = \pi \sigma 2a/E$, was considered. G is the crack extension force, σ is the stress normal to the crack direction, $2a$ is crack length and E is Young's Modulus. This approximation may be considered only when the existing plastic deformation is limited to the immediate vicinity of the crack front. Data of some of the laboratory tests are plotted as average stress versus crack length in Fig. 15. Curves for three theoretical values of G are also shown. The average stress for the specimens containing cracks 4 in. and longer was the $(PD/4t)$ stress at fracture unless indicated otherwise. All of the G values for cracks longer than 4 in. fell within the band of 200 to 100 in. lb./sq. in.

Some of the 4-in. flaws and all of those less than 4 in. in length were stressed in a somewhat different manner than the larger flaws. Various degrees of residual or reaction stresses were applied in the area of the flaw front, as well as in the path into which the fracture was to propagate. The lower value plotted in Fig. 15 for each of the specimens containing flaws less than 4 in. long is the $(PD/4t)$ stress required to produce fracture after some amount of residual stress was applied. The upper point for each specimen was obtained by adding the residual stress, calculated from strain measurements, to the stress, calculated from the expression $PD/4t$. The difference in stress between the two points for each specimen, therefore, is the residual stress as measured 2 in. from the flaw front. The stress at this location was not affected appreciably by the flaw. Figure 15 shows that the total applied and residual stresses of several of the specimens (upper point for each specimen) were considerably higher than the stress required to give a G value of 200 in. lb/sq in. However, the average stress at an area of sufficient distance from the flaw to be virtually unaffected by the geometry of the flaw was less than the sum of the residual and applied stresses. The reason for this was that both the residual and applied stresses when measured separately were in the elastic range. When the two stresses were superimposed, however, the steel behaved plastically. Consequently, the sum of the residual and applied stresses (measured separately) was not equal to, but was greater than, the actual stress.

The stress computed from the strain measured at a point 2 in. from the flaw front was approximately 36,000 psi for all the specimens containing flaws 4 in. or less in length, although there was considerable strain in the order of 0.005 in./in. at this point. However, at this strain level, a great difference in strain would not affect the calculated stress appreciably because of the relationship between stress and strain in the plastic range. The applied fracture stress of 36,000 psi gives a G value between 100 and 200 in. lb/sq in. for most of the tests. One of the specimens containing a 4-in. weld flaw failed at much lower recorded average stress than other specimens of equal flaw lengths. The residual and reaction stresses for this specimen were furnished by the parallel weld technique. Although the amount of strain 2 in. from the front was low, the strain at the flaw front was quite high. It is the strain at the flaw front that determines whether or not fracture initiates. One problem that arose from the introduction of residual and reaction stresses by welding was the difficulty in obtaining a uniform stress pattern between the two parallel welds. Although great care was taken to obtain uniformity in welding, the stopping and starting of an electrode or a difference in size of weld bead affected the magnitude of the residual stress.

No fractures were initiated from the 1-in. flaws. On the basis of the energy-force concept, which seemed to correlate with the fractures longer than 1 in. it would be expected that a rather high stress would be required to initiate the fracture from the small 1-in. flaws. The methods used in this study did not produce sufficient stress to initiate fracture at the tips of the 1-in. flaws.

The test results from this study have shown that brittle fractures may initiate from weld flaws at applied stresses much lower than the yield strength of the material. It is very difficult to judge the largest flaw that can be tolerated in a welded structure such as a ship. The state of stress in the area of the flaw front is just as important as the length of the flaw, if not more so. For example, a relatively large flaw of about 16 in. that is contained in a structure so loaded that the tensile stress is parallel to the flaw (a uniaxial stress system) may never be the source of fracture initiation. In another instance, a 1-in. flaw in a ship deck-plate weld that joins a chock or some other attachment to the deck may be potentially dangerous because the state of stress is very complex (constrained in three

dimensions). In order to initiate a brittle fracture in each of these cases, the test temperature must be below a certain value; the more complex the state of stress, the higher the temperature at which a brittle fracture might initiate. Of course, the size of the flaw has a direct effect on the state of stress at the flaw front; that is, the elastic stress concentration is increased for a given system with increase in flaw length. This is illustrated in this research by the fact that the applied fracture stress decreased with length of flaw.

In general, the data indicate that very close inspection should be exercised in critical areas (of high stress concentration) and weld flaws greater than 2 in. should be removed. Whereas, in other areas of a structure that are loaded uniaxially, larger weld flaws can be tolerated.

Summary

These studies were concerned with the initiation of brittle fractures from flaws less than 4 in. in length. It was desirable to determine the effect of residual and reaction stresses on the applied stress required to initiate brittle fractures from various types of flaws.

It is believed that the term "reaction stresses" most clearly defines the stresses that were of most concern in this study. The various techniques, such as the welding and the mechanical devices that were used to give an auxiliary stress in the area of the flaw front, were discussed in detail in the body of the paper. Generally, the stresses in the immediate vicinity of a weld deposit that are the result of welding are considered residual stresses, reaction stresses are the stresses resulting from two bodies acting against each other. This reaction stress may be removed by separating the material between the two acting bodies. In this work, weld deposits and a hydraulic ram were used as the acting bodies that produced the reaction stress.

Flaws having different radii at the point of initiation were studied in this investigation. Test specimens were prepared and tested in an attempt to simulate some of the service conditions that could exist and be the source of brittle fracture initiation at a low applied fracture stress.

The following are the important findings with regard to the testing technique obtained from this investigation:

1. Fractures were not initiated from flaws less than 4 in. in length from the load (33,000 psi) applied only by hydrostatic pressure on the sphere. However, fractures were initiated from these flaws by superimposing an auxiliary stress in the material at the flaw front in addition to the stress produced from the hydrostatic pressure on the wall of the sphere.

2. Sufficient elastic energy was stored in the wall of the sphere (testing apparatus) to propagate the fracture through the ABS-B steel after it was initiated.

3. The steel of high notch toughness in the sphere wall was capable of stopping the fracture without serious damage to the sphere.

4. Fast-running brittle fractures were deflected so that the fracture propagated in the weld joint between the test specimen and the sphere; this aided in preventing damage to the sphere wall.

With regard to actual weld flaws and simulated weld flaws (jeweler's saw cuts), it may be concluded:

1. Reaction and residual stresses can be an important part of the total stress required to initiate a fracture. The greater the reaction and residual stresses, the lower the applied stress required to initiate the fracture.

2. Length of flaw appeared to have little influence on the total stress (as measured at the flaw front) required to initiate fracture.

3. Sufficient residual and/or reaction stresses from welding were introduced in the area of flaw front to cause the initiation of brittle fracture at 6000 psi or less applied stress.

4. Reaction stresses, applied by a mechanical mechanism similar to that used to jack plates in place during the fabrication of ships, contributed to the initiation of brittle fractures at $(PD/4t)$ stresses of one-half or less the yield strength of the ABS-B steel.

5. Considerable plastic strain occurred on the surface of the plate at the flaw front prior to the initiation of fracture. In some specimens, the amount of plastic strain decreased with increase in severity of the crack or notch.

6. Less strain was recorded prior to fracture at the flaw front of buried flaws (as measured by strain gages on the plate surface), than for full-depth flaws. The exact sequence and progress of fracture was not determined.

7. The closer the state of stress at the flaw front approaches triaxiality, the lower the applied fracture stress. For example, the applied fracture stress of a "through-plate" welded structure was 6000 psi, as compared with 33,000 psi for a flaw of equal length stressed in biaxial tension only.

8. The data indicate that weld flaws greater than 2 in. may be dangerous and may be the source of fracture initiation, provided the flaw front is in a sufficiently triaxial stress field. In a biaxial-tension stress field, flaws 4 in. or greater in length may be the source of brittle-fracture initiation at applied fracture stresses lower than the yield strength of the ABS-B steel. By introducing a third structural member, thereby decreasing the opportunity for plastic strain, the applied stress required for fracture was as low as 10 to 15 % of the yield strength of the ship steel.

9. This study has shown that it is quite difficult to initiate brittle fractures from flaws less than 4 in. in length. In structures that are stressed in biaxial tension, it appears that rather large flaws could be tolerated; furthermore, there are without doubt areas in a ship structure where the state of stress is even less complicated than biaxial tension, and the total stress is very low at all times. In these areas, rather large flaws may not be harmful. Basically, the information gained in this study illustrates that if the designer has a general idea of the state of stress in a welded structure, he can predict the limitations of the soundness requirements of the weld deposit. In some areas of a structure, it may be virtually impossible to design so that some degree of triaxiality does not exist. In these areas, very close inspection should be exercised, because a very small flaw may be potentially dangerous.

Future Work

It has been domonstrated that residual or reaction stresses play a very important role in the total stress required to initiate brittle fracture. As the state of stress at the flaw front approaches triaxial tension, the applied stress level required to initiate fracture decreases. Experiments could be designed whereby various states of stress exist, and a different applied fracture stress would be recorded for each condition. Instead of pursuing further work in this direction, however, it seems that some consideration should be given to methods of reducing the residual and reaction stresses that are known to exist in welded structures. Perhaps these stresses need not be eliminated but redistributed over a greater volume of metal, so that stress concentrations of high magnitude are eliminated.

Behavior under residual and reaction stresses can be markedly influenced by the structural configuration and volume of metal being tested. If a large volume of metal is under residual stress, then upon the application of an applied load, little redistribution of the stress occurs. In the work described in this report, the volume of metal under reaction or residual stress was relatively small, so that on application of the tensile load, there was probably a redistribution of stresses that permitted the original highly stressed material to strain in a nonlinear manner. If a greater amount of material in the region of the flaw front were subjected to residual stress, brittle fracture might occur at even lower applied stresses than were recorded in this study.

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Multilingual Collection of Terms

A third part has just been issued to this valuable series of terms for welding and allied processes in twelve languages (Danish, Dutch, English, Finnish, French, German, Italian, Norwegian, Serbo-Croat, Slovene, Spanish and Swedish). It deals with arc welding. The terms adopted are those established by common usage in each country.

The indexing follows the style of previous parts (which dealt with gas welding, general terms for welding procedure, characteristics and inspection of welds) and allows easy translation of a term or expression from one language to another.

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Brittle-Fracture Strength of Welded Spherical Container

Influence of residual stress and effects of stress-relieving heat treatments are investigated

BY HIROSHI KIHARA, KOICHI MASUBUCHI, AND HIROSHI ISHII

ABSTRACT. Experimental investigations were conducted on brittle-fracture strength of welded spherical containers. Emphasis of the experiment was placed on the investigation of influence of residual stress and effects of stress-relieving treatments on fracture strength. Spheres of 1500-mm (59 in.) diam. were used. The thickness of the plate at the test part was 25 mm (1 in.). Fracture tests were carried out by applying hydrostatic pressure at various temperatures. It was found that the complete fracture of sphere can be realized at a stress well below the yield stress of the material when such unfavorable factors as the use of material of low notch toughness, low temperature, existence of sharp notch and high-tensile residual stress are superimposed. In other words, residual stress may bring about a serious decrease in load-carrying capacity of welded structures under certain conditions. Effects of mechanical stress relieving and stress-relieving heat treatment on fracture strength also were studied, and it has been proved that these treatments have a beneficial effect on fracture strength.

Introduction

In recent years, there has been a demand for large welded structures in various fields of industry, and many large spherical containers have been constructed for petroleum, chemical and other plants. In building these large welded structures, a very important problem has been that of preventing a brittle fracture which may bring about a catastrophic failure of the structure under service conditions.

It is the nature of brittle fracture that actual damage usually occurs at a rather low stress. An examination of service failures has indicated that fracture occurred at stress far below the yield stress of the material. On the other hand, it has been observed that the nominal fracture stress of a notched test specimen is as high as the yield stress, even when the specimen contains very sharp cracks. Because of this discrepancy between service and experimental experience, studies are being conducted by many researchers to investigate the mechanism of brittle fracture at low stress levels in welded structures.

The influence of residual stress is almost negligible in the case of ductile fracture; however, residual stress may play an important role in the case of brittle fracture. Consequently, it is important to consider the influence of residual stress on the strength of welded structures, as high residual stress is usually present.

The authors[1] have recently conducted an experimental investigation and found that residual stress may have a serious influence on the brittle fracture of welded structures. Tests were carried out on wide-plate longitudinal weld joints containing a sharp transverse notch, and it was found that the complete fracture of a welded joint could be brought about by merely applying a low stress when unfavorable effects of residual stress and the existence of a sharp notch are superimposed.

An experimental investigation on fracture strength of welded spherical containers has been undertaken by the present authors for the purpose of obtaining fundamental knowledge which can be applied to the design and fabrication of welded pressure vessels. The emphasis in the research was placed on the investigation of influence of residual stress and effect of stress-relieving heat treatment on brittle fracture in large-scale models.

Method of Testing

Sphere

Fracture tests were carried out on spheres of 1500-mm (59 in.) inner diameter. A sketch of these vessels is shown in Fig. 1.

Two types of apparatus, disk type and sphere type, were used in the experiment. In a disk-type apparatus, a circular-disk test plate 900 mm(35 in.) in diameter was welded into the wall of the main part of the sphere, as shown in Fig. 1(a). The specimens were made with steel plates of low notch toughness 25 mm (1 in.) thick. The main part of the sphere was made with steel plates of high toughness 41 mm ($1^5/_8$ in.) thick in order to limit the propagation of brittle fracture in the testing vessel as much as possible. The same test vessel was used several times by changing the specimen welded into it. Most of the experiments reported here were conducted with the disk-type apparatus because of the lower cost of this type of test.

A fracture test of a whole sphere also was conducted in order to investigate the state of fracture which may occur in actual spheres. In this case, a whole sphere was made with a material of the same quality and thickness as shown in Fig. 1(b).

A longitudinal butt joint was made along the centerline of a specimen, and a sharp transverse notch was cut at the middle part of the longitudinal weld as shown schematically in Fig. 1. Welding procedures of the longitudinal joint were as follows:

Joint details: unsymmetric X-joint, as shown in Fig. 2.
Welding electrode: lime-titania type (JIS,* D4300), 4-mm ($^5/_{32}$ in.) diam.
Welding current: 170 to 190 amp.

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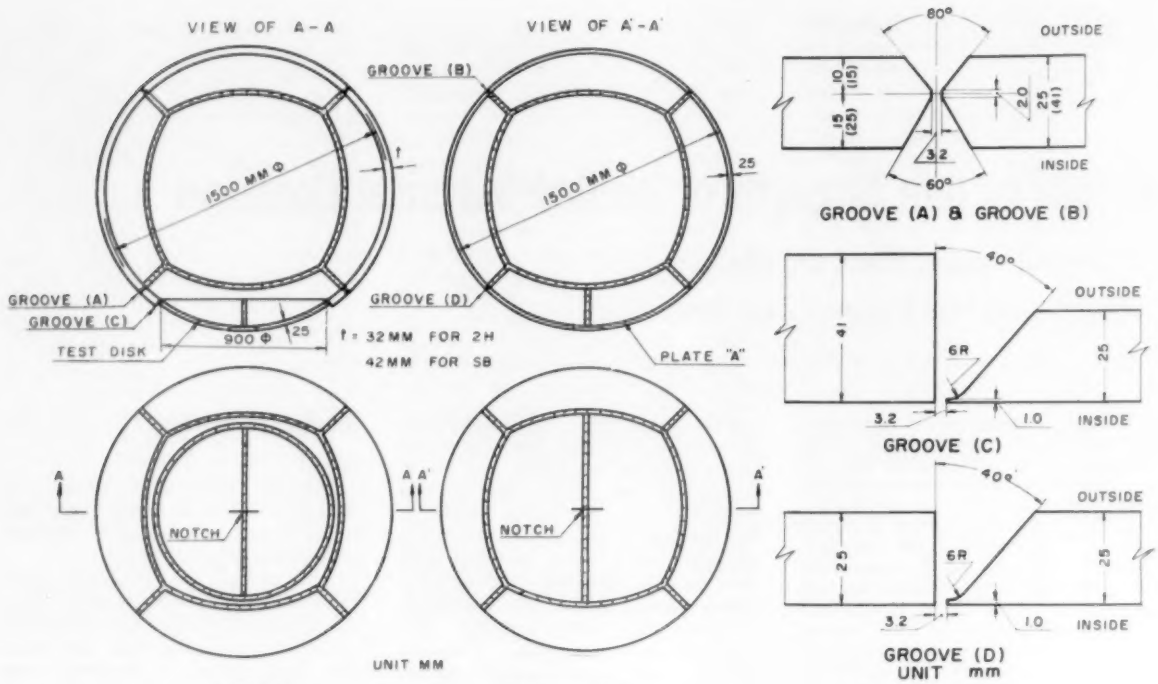
Paper presented at the AWS National Fall Meeting held in Detroit, Mich., Sept. 28 to Oct. 1, 1959.

* Japan Industrial Standard.



(a) Disk type (b) Sphere type (c) Details of joint

Fig. 1—Test sphere

Details of the notch are shown in Fig. 2. The notch was cut after the completion of the longitudinal weld in the following way. First, the middle part of the notch, 1.5 mm (0.06 in.) wide and approximately 34 mm ($1^3/_8$ in.) long, was made by means of a drill and a machine saw. The second-step notches, 0.2 mm (0.008 in.) wide and 3 mm ($^1/_8$ in.) long, were next cut into the ends of this sawed notch by an electric-sparking method. The length of notch was designed to be longer than the width of the longitudinal weld bead but short enough to have its ends in the region of high-tensile residual stress. Sheets of aluminum 2.0 mm (0.08 in.) thick and steel 1.5 mm (0.06 in.) thick were attached to the inner surface of a specimen in order to prevent leakage of brine through the notch during testing. An example of notch is shown in Fig. 3.

Specimens thus prepared were welded into the wall of a main sphere previously fabricated. A single-beveled V-joint as shown in Fig. 1(c), groove *D*, was used as a circular weld joint between the specimen and the main wall of the test vessel. Welding was done with electrodes of low-hydrogen type (JIS D4316), 4-mm ($^5/_{32}$ in.) or 5-mm ($^3/_{16}$ in.) diam, in order to obtain a weld metal of high ductility.

In fabricating the sphere-type test, nearly the same procedures as those used in the disk-type tests were adopted. A part of the sphere, which is called plate A, was made in the same way as the test plate in the disk-type apparatus. A transverse notch was made in the middle part of a longitudinal weld. The plate A was then welded into the wall of the main sphere which had been fabricated with the same steel of poor notch ductility. All weld joints in the sphere-type test vessel were made with electrodes of lime-titania type.

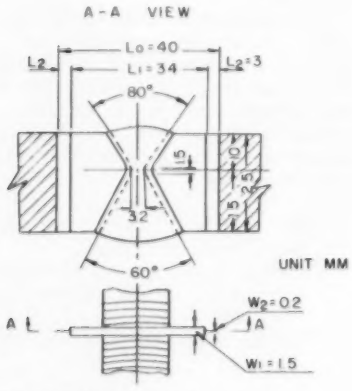


Fig. 2—Details of notch

Material

Mild-steel plates of low notch toughness were used as specimens. Properties of the material tested are shown in Table 1. This steel belongs to Class SS-41 of Japan Industrial Standards, and the code number of this steel in this report is designated as Steel SS.

The spherical test vessel used in the disk-type tests was made with plates of JIS SB-42-B, which is a steel used for boiler construction.

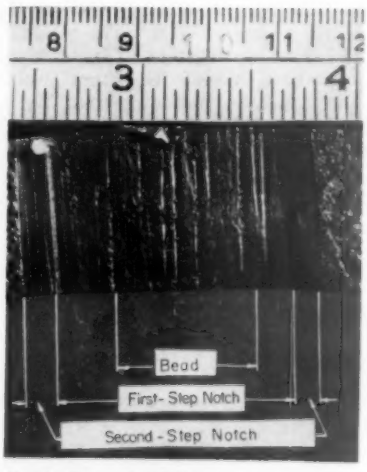


Fig. 3—Example of notch

Table 1—Properties of Material Tested (Steel SS)

Chemical composition:

Element	Ladle Analysis, %
C	0.22
Si	Trace
Mn	0.39
P	0.032
S	0.032

Mechanical properties:
- Yield strength, 26.8 kg/mm²
- Ultimate strength, 46.1 kg/mm²
- Elongation (GL = 200 mm), 27%

Notch toughness
- Standard V-Charpy test
  - Energy absorption at 0° C, 1.0 kg-m/cm²
  - 15 ft-lb transition temperature, 29° C
  - Shear transition temperature, 48° C
- Tipper test
  - Shear transition temperature, 43.5° C

Testing Methods

Fracture tests of spheres were carried out in the explosion test room located in the Transportation Technical Research Institute. Loading was done with hydrostatic pressure after the test vessel had been cooled or warmed to the desired test temperature. The test vessel, filled with calcium-chloride brine, was immersed in a bath filled with methanol solution cooled by carbon dioxide. In the sphere tests, the brine was circulated in order to obtain a uniform temperature distribution. In the disk tests, a part of the sphere surrounding the specimen was locally cooled. Warm water was used when the test temperature was higher than the room temperature. Temperatures were measured by thermocouples attached to several points of the sphere.

The value of applied stress was calculated from the measured value of hydrostatic pressure using the following equation:

$$\sigma = \frac{p \cdot D}{4t}$$

where:

σ = skin stress, kg/mm²
p = pressure, kg/mm²
D = diameter of sphere, mm
t = thickness of sphere shell, mm

Pressure was measured with a pressure gage. Measurement of surface strains were made on some specimens using resistance strain gages.

Conditions of Experiment and Method of Stress Relieving

The following series of experiments was conducted.

Series A. Influence of residual welding stress on fracture strength.

Series B. Effect of stress-relieving heat treatment on fracture strength

In Series A, 10 specimens, including the one which was conducted with the sphere-type apparatus, were tested at various temperatures.

In Series B, a small number of tests were conducted on specimens

Table 2—Summary of Fracture Strength

Test condition	Specimen code No.	Mechanical stress relieving Temperature, °C[a] Initial	Final	Stress, kg/mm²	Fracture test Temperature, °C[a] Initial	Final	Stress,[b] kg/mm²	Mode of fracture[c]
As-welded	Disk No. 1	..	..	..	−34.0	−33.5	9.0	S
	Disk No. 2	..	..	..	−37.4	−36.0	5.6	S
	Disk No. 3	..	..	..	15.5	16.7	8.1	P
	Disk No. 5	..	..	..	5.4	5.7	12.9	S
	Disk No. 6[d]	..	..	..	−5.3	−4.0	9.4	S
	Disk No. 7	..	..	..	26.2	27.0	12.1	S
	Disk No. 8	..	..	..	24.8	27.2	11.5	S
	Disk No. 9	..	..	..	29.5	29.9	19.8	S
	Disk No. 10	..	..	..	41.8	42.0	15.0	S
	Sphere No. 1	..	..	..	−24.8	−24.3	10.9	S
Mechanically stress-relieved	Disk No. 11	53.0	50.4	19.8	−31.8	−31.0	19.2	S
	Disk No. 12	54.8	52.1	25.9	−34.0	−32.8	26.2	H
Annealed[e]	Disk No. 13	..	..	..	−41.3	−40.3	31.6	H
	Disk No. 14	..	..	..	−29.6	−28.9	21.5	S

[a] Temperature shown in the table indicates the value in the middle of plate thickness near the notch.
[b] Stress is calculated from measured value of pressure.
[c] Mode of fracture: S = single-stage fracture at low stress level, P = partial fracture, H = fracture at high stress level.
[d] Reinforcement of longitudinal weld was removed.
[e] Stress-relieving heat treatment at 650° C for 1 hr.

Table 3—Summary of Fracture Appearance

Specimen code No.	No. of crack initiations from weld flaw	No. of branch points Test plate	Circular weld	Surrounding plate	Crack length up to the first branch, mm	Crack length, mm Test plate	Circular weld	Surrounding plate	Total	Shear percentage %
Disk No. 1	..	..	..	..	>500	910	70	428	1408	..
Disk No. 2	..	..	1	1	>500	960	70	165	1195	..
Disk No. 3	..	..	..	..	>500	122	..	..	122	..
Disk No. 5	..	2	..	..	280 and 420	1366	140	1491	2997	1.3
Disk No. 6	..	1	..	1	500	1010	70	984	2064	1.6
Disk No. 7	..	2	..	..	395 and 415	1120	80	256	1456	6.4
Disk No. 8	..	1	1	..	470	922	70	78	1070	6.6
Disk No. 9	..	..	..	..	>500	919	75	771	1765	6.6
Disk No. 10	..	..	..	..	>500	915	48	..	963	17.8
Sphere No. 1	..	1	..	2	145	1885[a]	105	3439	5429	1.2
Disk No. 11	8	3	4	7	>500	1754	1075	2810	5638	..
Disk No. 12	3	10	..	7	162 and 209	3532	452	5762	9746	..
Disk No. 13	2	7	3	..	61 and 102	2839	477	3249	6565	..
Disk No. 14	1	3	2	..	181 and 209	1390	794	2139	4323	..

[a] Plate A in Fig. 1 corresponds to test plate.

which had been stress relieved to some extent by mechanical stress relieving and also on specimens stress relieved by heat treatment.

Mechanical stress relieving was done by loading hydrostatically to a pre-selected stress level. For this purpose the test vessel with the disk specimen welded into it was loaded by hydrostatic pressure in the same way as a fracture test. The loading was done at a temperature high enough to prevent brittle fracture. Two specimens, disk no. 11 and disk no. 12, were stress relieved in this way. One was loaded up to about 20 kg/mm² (28,000 psi) hoop stress, and the other about 26 kg/mm² (37,000 psi) which is just below the yield stress. Both specimens were loaded at about 50° C (122° F). The fracture tests of these specimens were conducted at low temperatures, about −30° C (−22° F).

Investigation of effect of stress-relieving heat treatment was conducted using two specimens. In these cases, a spherical test specimen was put into a furnace and heated up to 650° C (1200° F) and kept for about 1 hr at that temperature. After being cooled to 250° C (480° F) in the furnace, the sphere was air cooled. The cooling rate in the furnace was approximately 31° C per hour (56° F per hour). The fracture tests of these specimens were conducted at low temperatures.

Test Results

Fracture Strength in As-welded Condition

The results obtained in these experiments are listed in Tables 2 and 3. The values of testing temperature and stress at fracture are given in Table 2, and the values indicating the state of fracture such as the length of crack, number of branches, etc., are given in Table 3.

Relations between testing temperature and the value of fracture stress in as-welded condition are shown in Fig. 4. In all specimens tested at a temperature below 42° C (108° F), a fracture occurred at a stress lower than the yield stress of the material. In these cases, a fracture extended through the whole width of the test specimen with an exception of disk no. 3, in which a partial fracture took place. In the case of disk no. 3 tested at 16.7° C (62° F), a fracture started at a stress of 8.1 kg/mm² (11,500 psi), but the crack extended only 120 mm (4.7 in.) and stopped. Values of applied stress at the fracture were usually much lower than the yield stress except in the case of disk no. 9 in which the fracture occurred at 19.8 kg/mm² (28,000 psi). Excepting the above-mentioned two cases, complete fracture of the test specimen was observed at a stress well below the yield stress. In the case of sphere no. 1, the fracture occurred at 10.9 kg/mm² (15,500 psi) hoop stress and extended to more than 5 m (200 in.) in its total length. The value of stress at fracture obtained in the spherical specimen showed no particular difference from those obtained in disk-type specimens. As shown in Fig. 4, there is a tendency for the value of fracture stress to increase as the temperature becomes higher.

When the testing temperature becomes higher than a certain critical temperature, the mode of fracture changes from cleavage to shear and the value of fracture stress increases abruptly. In the case of disk no. 12 tested at 52.1° C (126° F), fracture did not occur before yielding; whereas, a complete fracture occurred at 15.0

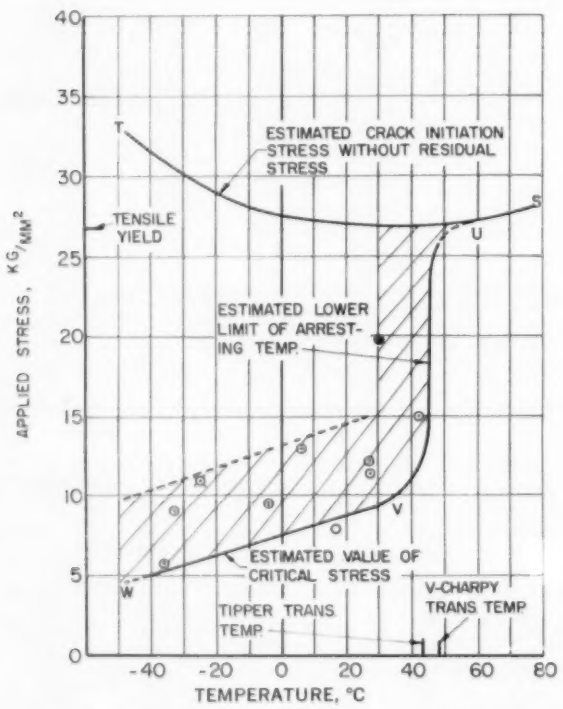


Fig. 4—Relation between test temperature and applied stress for as-welded specimen. Note: ⊙ = disk-type apparatus; ⊠ = sphere-type apparatus (Sphere No. 1); ⊗ = disk-type apparatus in which reinforcement is removed (Disk No. 6); ○ = disk-type specimen which showed partial fracture (Disk No. 3)

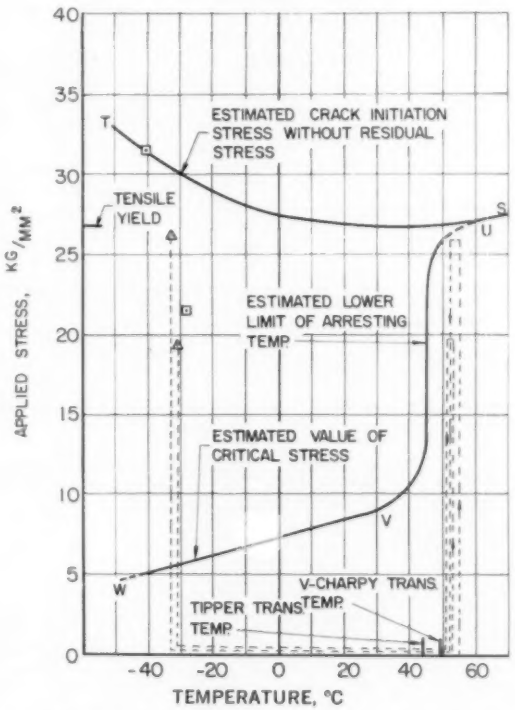


Fig. 5—Relation between test temperature and applied stress for stress-relieved specimens. Note: △ = mechanically stress relieved; ⊡ = thermally stress relieved

kg/mm² (21,000 psi) at 42.0° C (108° F). This fact shows that a sudden increase in fracture stress may take place in the temperature range between 42° C (108° F) and 52° C (126° F). The loading of disk no. 12 above 26 kg/mm² (37,000 psi) was not conducted, and this specimen was loaded again at a low temperature as a specimen mechanically stress relieved.

The reason for the rather high fracture stress obtained in disk no. 9 has not yet been determined. The reduction of residual stress may be considered as a possible reason, as the weld bead had been ground off before testing. Scatter of results in the temperature region very close to the transition temperature may also be the reason.

Effect of Stress-relieving Treatment on Fracture Strength

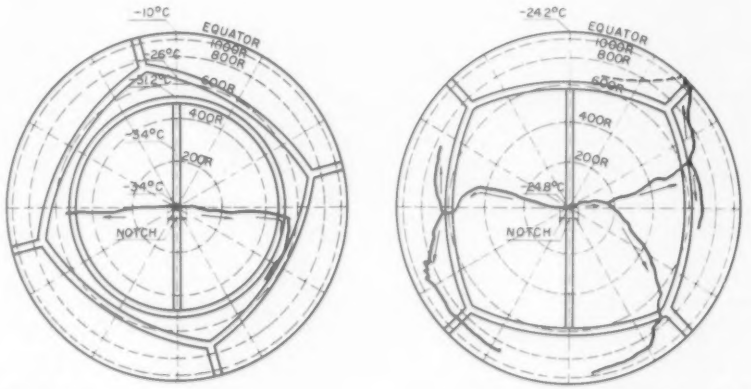
Fracture characteristics of specimens on which mechanical stress relieving or stress-relieving heat treatment was applied before testing are shown in Fig. 5. Mechanical stress relieving raised the fracture stress to a value near the stress level used for stress relieving. One specimen thermally stress relieved and tested at −40° C (−40° F) fractured at a stress of 31.6 kg/mm² (45,000 psi), and the other thermally stress-relieved specimen tested at −29° C (−20° F) fractured at a stress of 21.5 kg/mm² (31,000 psi).

Fracture Appearance

The results obtained in tests such as total length of notch, number and locations of initiation points of fracture, number of branch points in fracture, crack length, percentage of shear fracture, etc., are summarized in Table 3. Sketches of some of the fractures are shown in Fig. 6. Besides the path of fracture, location of fracture-initiation points other than the previously made notch root (small white circle), direction of crack propagation (arrow symbols) and temperature distribution of a sphere at the time of starting loading are shown in Fig. 6.

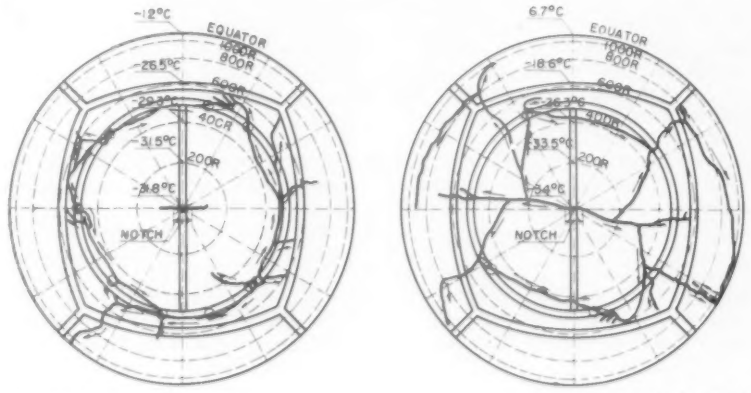
In the as-welded specimens, fracture always initiated from the notch and propagated along the direction of the notch. In all cases except disk no. 3, in which a partial fracture took place, a fracture extended to the edges of the disk specimen and stopped at some point in the tougher material of the test vessel. Some fractures branched. These branches sometimes occurred in the test disk itself, but they also appeared in the circumferential weld and in the test vessel.

Mechanical stress relieving and stress-relieving heat treatment had significant effects on fracture appearance. In stress-relieved specimens, some additional fractures usually initiated from weld flaws in the circular weld joining the test disk to the vessel. In the case of disk no. 11, the fractures started mainly from weld flaws in the circular weld and the test disk was completely separated from the main sphere. The crack from the notch in the specimen propagated in a short distance and stopped. Branches of fracture were more liable to occur in stress-relieved specimens than as-welded ones.



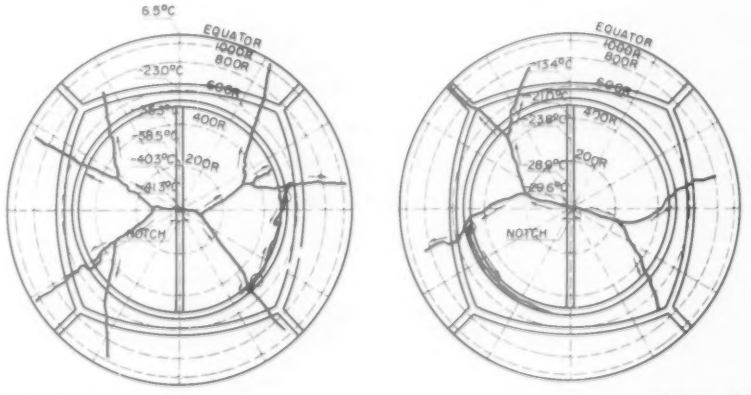
Disk No. 1 — Sphere No. 1

A. As welded



Disk No. 11 — Disk No. 12

B. Mechanically stress relieved



Disk No. 13 — Disk No. 14

C. Thermally stress relieved

Fig. 6—Sketches of fracture

In as-welded specimens, branches usually occurred after the initial fracture had run more than 300 mm (12 in.); however, in stress-relieved specimens, branches occurred in much shorter distances, as shown in Table 3.

The fracture was completely brittle in specimens tested at temperatures below 27° C (81° F). A shear lip was observed in specimens tested at a temperature higher than 27° C (81° F), and the amount of shear lip increased as the temperature became higher. A thumbnail appearance was observed at the end of the partial fracture which occurred in disk no. 3.

Discussion and Conclusion

Fracture Strength of Spherical Container in As-welded Condition

Analyzing the experimental results obtained in the previous experiments on wide-plate weld joints,[1] the authors have suggested a theory for the mechanism of the influence of residual stress on brittle fracture. The theory is based on the concepts of crack initiation and propagation characteristics of base plate. The main points of the theory are as follows: When the temperature is high enough, complete fracture of a welded joint at low stress level does not occur, and the influence of residual stress on load-carrying capacity is almost negligible. When the temperature is low enough, residual stress may have a serious influence on the fracture strength of a welded joint. In the case of a specimen free from residual stress, fracture occurs after general yielding even if the specimen contains a very sharp crack. However, if a sharp notch is located in a region of high-tensile residual stress, a fracture may initiate at a low stress level. In this case, the following two different phenomena may take place in accordance with the value of applied stress at crack initiation. If a crack initiates at a stress lower than the critical stress for the base plate, a partial fracture occurs and complete fracture does not occur until general yielding has set in. On the other hand, if a crack initiates at a stress higher than the critical stress, a complete fracture in a single stage may occur at a low stress. In other words, a remarkable decrease in load-carrying capacity may be brought about by the existence of residual stress.

The authors have also tried to analyze the results obtained in this experiment on welded spheres and have found that the results obtained in this experiment can be clearly understood by the above-mentioned theory.

Some estimations of crack initiation and propagation characteristics of steel from experimental results also have been tried in the same way as has been suggested in the previous report, and the results are shown in Figs. 4 and 5. Curve ST shows the value of stress necessary to initiate a fracture in a specimen having a sharp notch but which does not contain residual stress. Curve UVW shows the characteristics of crack propagation. The value of critical stress seems to increase as the temperature becomes higher. The arresting temperature is estimated to be between 42° C (108° F) and 52° C (126° F). It is also found that the arresting temperature seems to have a close relationship to the transition temperature obtained by a Tipper test, as it has been pointed out in a previous report.

Effect of Stress-relieving Treatment

It has been ascertained that mechanical stress relieving and stress-relieving heat treatment have beneficial effects in lessening the chance of brittle fracture.

In the case of mechanically stress-relieved specimens, fracture occurred at nearly the same stress as was used for stress relieving. Mechanical stress relieving by applying a stress cycle at high temperature may be applicable in such a simple structure as a pressure vessel, in which the state of loading in service conditions can be realized in a certain load test. The specimens heat treated at 650° C (1200° F) for 1 hr also showed a high fracture stress. A remarkable difference in the state of fracture was observed between as-welded specimens and stress-relieved ones.

Acknowledgment

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Reference

1. Kihara, H., and Masubuchi, K., "Effect of Residual Stress on Brittle Fracture," WELDING JOURNAL, **38** (4), Research Suppl., 159-s to 168-s (1959).

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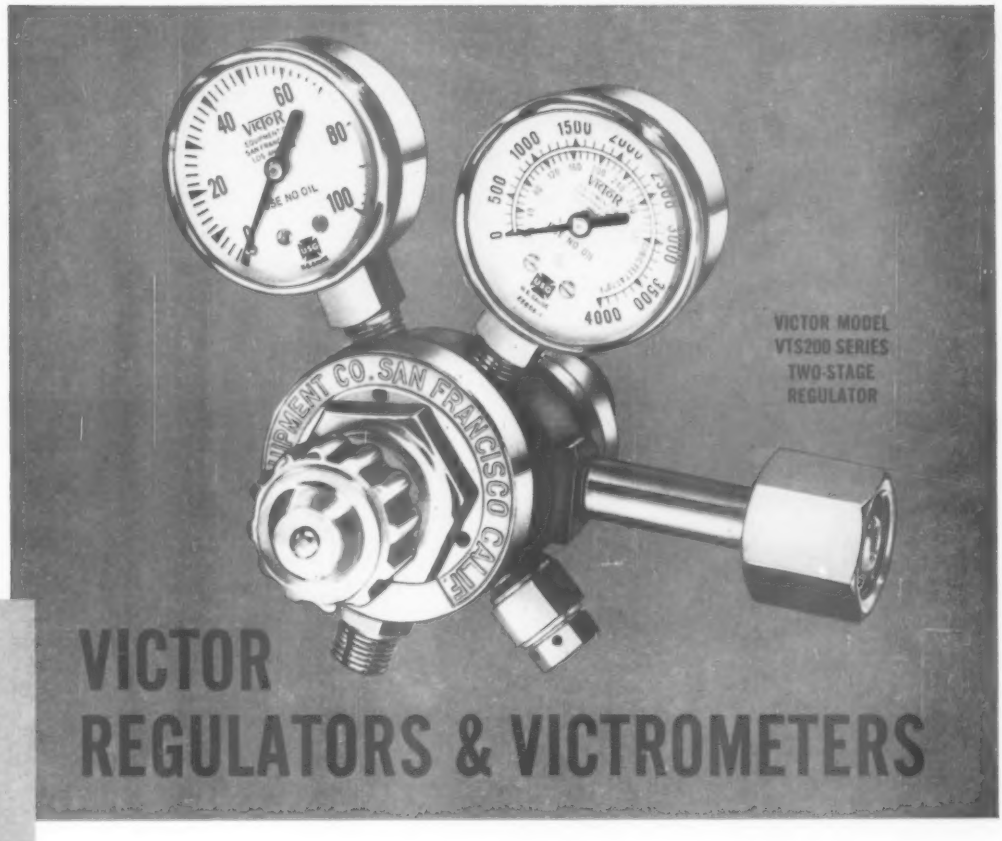

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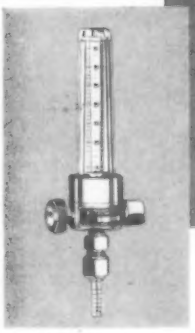

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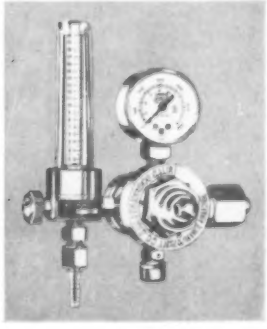

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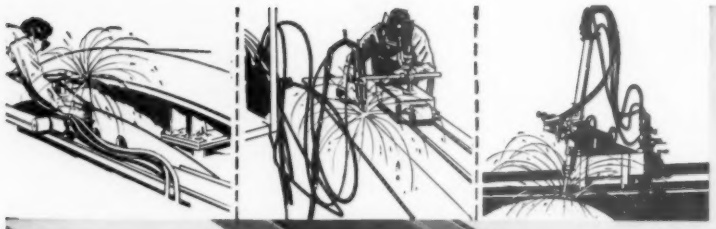

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